GUIDE TO THE STUDY OF NATURE (BOTANY)

Jas Danford Jr.
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BY

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PREFACE

THE present volume is based, almost entirely, on the course which I follow in teaching Nature Study, from the botanical aspect, to the students of the Glasgow Provincial Committee for the Training of Teachers. The object of such a course is not so much to impart a knowledge of botanical facts as to train the student in the way of seeking this knowledge. As much, therefore, of statements of facts are given as will prevent the student from coming to a standstill for want of it. By this means the information that is placed in the note-books becomes of considerably greater value than notes culled from text-books. In the case of the more difficult parts of the subject, however, experience has shown that it is often necessary to communicate the whole of the matter to the students, letting them subsequently verify the facts for themselves. I have therefore treated the more difficult parts with greater fullness. It is hoped that sufficient training will have been given, by following the general method adopted in this book, to enable the student to strike out independently for himself (or herself) along collateral or different lines; for in such a wide subject it is not possible within the scope of such a book as this to cover more than a part of the subject. The attitude towards the study of Nature is, however, the main thing, and if the correct attitude has been attained, by

following a particular course of study, the question as to the largeness or smallness of the accumulation of knowledge that has been thereby achieved may be relegated to a secondary place.

In the preparation of this book I must acknowledge my indebtedness to several of my students who have helped me, and particularly to my assistant, Miss Wanda Zamorska, for her help throughout the preparation of the book, and to my wife for help in the preparation of the drawings.

DAVID ELLIS.

GLASGOW, *March* 1912.

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BOTANY

I.—THE FLOWER

General Remarks (I).—A complete flower is made up of four parts. The two outer envelopes are known as *calyx* and *corolla* respectively. The calyx is made up of *sepals*, and the corolla of *petals*. Inside these we find the *stamens*, and the *carpels*.

Stamen is the name given to the organ which bears the *pollen grains*, and the bearer of the *ovules* is called a *carpel*. The ovules are those bodies which are fertilized by the pollen grains and which develop into seeds. A seed under favourable circumstances gives rise to a new plant.

Stamens and carpels are thus necessary for the production of seeds and are consequently indispensable. The calyx and corolla, however, are merely accessories for the purpose of protection and for the attraction of insects. In the case of flowers, which do not utilize insects or birds for this purpose, the calyx and corolla are not usually developed.

A carpel usually consists of 3 parts, a receptive surface for the pollen, called *stigma*, a neck, called *style*, and a body called *ovary* (Fig. 1a). Suppose a particular flower to possess 4 carpels. These 4 may be quite separate (Fig. 1b): or all the ovaries may be joined together, the styles and stigmas being free (Fig. 1c): or all the ovaries and all the styles may be

joined together, leaving only the stigmas free (Fig. 1d): or finally, ovaries, styles and stigmas may be completely fused (Fig. 1e).

Not only the carpels, but also the other parts of the flower, exhibit different modes of union. Thus in the primrose all the petals are joined together, whilst in the wallflower they are separate. Again there may be union between different parts of the flower: thus it is common to find the stamens

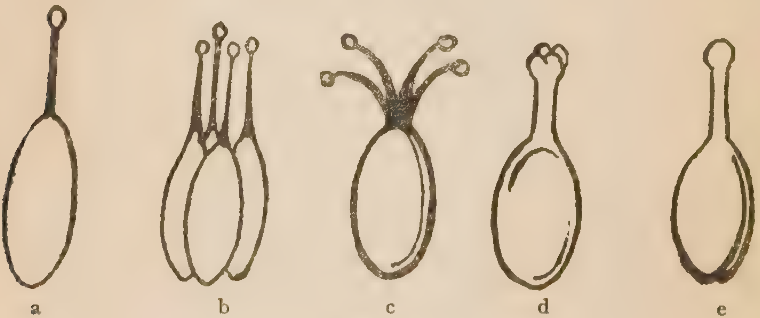


FIG. 1

attached to the petals; again petals and sepals are often found in attachment.

The student may now proceed to examine a few flowers. We may take the wallflower as an example, to illustrate the mode of procedure that should be followed.

Ex. 1. *Wallflower.*

Calyx.—Note colour, shape and number of sepals. Are the sepals separate, or joined together, or joined to the corolla? Make an enlarged drawing of one sepal.

Corolla.—Note colour, shape and number of petals. Are these separate, or joined together, or joined

to other parts of the flower? Make an enlarged drawing of a petal.

Stamens.—Make a drawing of the flower after having first removed the calyx and corolla. Next make 2 drawings of a stamen, much magnified (at least 3 ins. long), one showing the front view, the other the back view. Slit open the pollen-box and remove some of the pollen. If your magnifying-glass is strong enough, see if you can make out any details of structure.

Carpels.—Remove stamens and make a drawing of what is left of the flower, viz., the carpels.

Investigate the following points:

1. The number of carpels.

2. Whether the carpels are separate or joined together. If the carpels are joined together the number of carpels that have united is indicated by the number of stigmas, or if these are joined together, by the number of cavities in the ovary. *E.g.*, Fig. 2c indicates the presence of three carpels. Further, it may happen that even the number of cavities in the ovary is no indication of the number of carpels. Thus in Fig. 2a there is only one cavity but there are three carpels, because the ovules arise from three distinct places. In such cases the best rule to follow is this—"Count the cavities if there are more than one; count the number of places from which ovules arise if there is only one cavity." If separate, make a drawing of one carpel on a large scale. Cut open the ovary and find out the number and mode of arrangement of the ovules that are in-

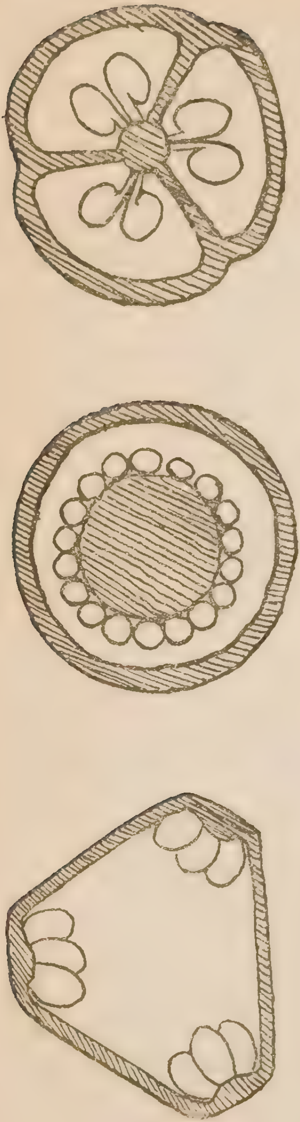


Fig. 2

Diagrammatic Sketch of Types of Arrangement of Ovules. Figures represent cross-sections of ovaries. In a the ovules are attached directly to the outer walls. In b and c the outer wall is free from ovules, these being attached, in b, to a central mass of tissue, and in c to the junction of the internal walls. The part of the ovary which bears the ovules is called a *placenta*.

a = parietal placentation. b = free central placentation. c = axile placentation.

side. It is preferable to cut a thin slice across the middle, and, before proceeding to investigate, take a glance at Figure 2.

Find out the mode of attachment of the ovules.

For the sake of practice several flowers should be examined. These should be chosen from large, conspicuous flowers, like the primrose, foxglove, snowdrop, lilies, etc., according to the time of year.

II.—THE FLOWER (*continued*)

General Remarks (II).—It is a general rule in Nature, applying both to the

animal and to the vegetable kingdom, that the offspring of very closely-related individuals are not as healthy as the offspring of individuals that are not quite so nearly related. Among flowers, the ovule which is fertilized * by pollen from the *same* flower, does not develop into as strong a seed as one which is fertilized by pollen drawn from *another* flower of the same kind. Hence we find all kinds of adaptations to prevent *self-pollination* and to secure *cross-pollination.*

There are 2 main methods of securing cross-pollination:

1. By the agency of the *wind*.
2. ,, ,, ,, ,, *insects*.

Wind-pollinated plants are characterized by—

1. Absence of fragrant and conspicuous flowers.
2. Abundance of pollen.

Insect-pollinated plants are characterized by having—

1. Fragrant and conspicuous flowers.
2. Honey.
3. Adaptations to enable the insect to find its way to the honey.
4. Adaptations for ensuring that the insect does not leave the flower without bearing with it some of the pollen.

In examining a flower from the point of view of fertilization, the following mode of procedure should be adopted.

1. Is the flower one that is likely to be wind-pollinated, or insect-pollinated?
2. If wind-pollinated answer the following questions:—
   a. Are the flowers isolated or clustered together?
   b. What structures are present besides the stamens and carpels?

* See Appendix for explanation of fertilization.

c. Is the pollen-box (anther) large or small?

d. Is there any fragrance such as would attract insects?

e. Are the flowers formed before or after the leaves?

In each case try to find out the advantage that accrues to the plant from the possession of each particular structure. Draw the flower or the cluster of flowers on a fairly large scale.

3. If a preliminary observation shows that the flower is *insect-pollinated,* the following points may be noted before the examination is further proceeded with. Open flowers of a regular pattern, which have their honey exposed to any chance insect visitor, are not so highly developed as closed flowers of irregular shape, in which the honey is accessible only to certain kinds of insects. The latter kind of flower, having more specialized structures, shows a higher stage of development.

Then proceed as follows:

a. Make notes on the colour and fragrance of the flower.

b. Ascertain the spot where the honey, if present, is located. It is usually placed at the bottom of the flower.

c. Imagining the insect on the point of alighting on the flower, see if there is any provision to facilitate its landing. It will generally be found, if the flower is irregular in shape, that the departure from the regular shape is such as would facilitate the landing.

d. Supposing the insect to have alighted, see if there are indications of *honey-guides* leading towards the honey. These are streaks or spots of different colour to the rest of the flower.

e. Find out what means, if any, are possessed by the flower to prevent the insect getting the honey away, without at the same time having its body covered with pollen. Hence examine the stamens carefully, note their position, and see whether they lie on the track between the landing-stage and the honey.

f. Note the number of stamens. Generally speaking the greater the specialization the fewer the stamens, because the chances of successful pollination are greater and therefore a smaller number of pollen grains will suffice.

g. Examine several specimens of the same flower and ascertain whether the stamens and stigmas are fully grown *at the same time*. If not, consider in what manner this would help *to prevent self-pollination*.

h. See if there is any provision on the stigma to prevent the pollen which have been carried there from falling off.

As many flowers as possible should be examined from this point of view, beginning with large or conspicuous examples, *e.g.*, foxglove, violet, toadflax, buttercup, primrose, etc. In all cases make large drawings. After a number of flowers have been examined they should be divided into 3 classes: wind-pollinated flowers, insect-pollinated regular flowers, and insect-pollinated irregular flowers. From your own observations write out the characteristics of each class.

III.—THE FLOWER (*continued*)

General Remarks (III).—After gaining practice by following the suggestions contained in the 2 preceding sections, the student will now be ready for the investigation of somewhat more difficult points in the structure of the flower.

A. Superior and Inferior Ovaries.—The ovary is *superior* when the calyx (and incidentally the petals and stamens) arise underneath the ovary, and *inferior* when the calyx arises from the top of it. The 2 kinds are diagrammatically represented in Fig. 3. It is useful to remember that a superior ovary is covered by the petals and sepals, whereas an inferior ovary is not.

B. Hypogynous, Epigynous and Perigynous Flowers.—The part of the flower-stalk which bears the floral parts is called the *thalamus*. If the carpels are formed at the top of the thalamus, the stamens, petals and sepals being inserted, in order, on the side of the thalamus, the flower is said to be *hypogynous* (Fig. 3A). If the thalamus takes any one of the forms represented in Fig. 4, A-E, the stamens, etc., are formed not *under* the carpels, but *around* them. In such cases the flower is said to be *perigynous*. Finally the thalamus may form a deep cup, the rim of which is closed together. The stamens, petals and sepals arise from the closed-in rim, whilst the carpels arise inside the closed cavity. Such a flower is said to be *epigynous* (Fig. 3B).

C. Floral Formula.—It is very convenient to be able to write down the main characteristics of a flower in an abbreviated manner.

K stands for calyx
C ,, ,, corolla
A ,, ,, stamens
G ,, ,, carpels

The number of the parts is written after each letter. Thus K4 means that the calyx consists of 4 sepals. Fusion is indicated thus ( ). Thus K (4)

A
FIG. 3

B
Inferior Ovary.
FIG. 3

means that the calyx consists of 4 joined sepals, A6 indicates the fact that the flower possesses 6 stamens. If the stamens are attached to the corolla, A and C are bracketed. The formula $[(C_5)A_5]$ indicates that the flower has 5 joined petals, 5 free stamens, and that the stamens and petals are joined together. A superior ovary is indicated by drawing a line *under* the number affixed to G, and an inferior ovary by drawing a line above this number, thus G $\underline{(3)}$ means that there are 3 joined carpels

of which the ovaries are superior, whilst $G\ \overline{(3)}$ indicates that the 3 carpels have inferior ovaries.

Examine as many flowers as possible with respect to

FIG. 4

Note that in D and E the stamens, petals and sepals are borne on a disc which encircles the ovary.

D = perigynous and inferior; E = perigynous and superior.

these points and illustrate by means of large drawings. It is advisable to make drawings of flowers which have been cut lengthwise through their middle.

IV.—THE SEED

General Remarks (IV).—An ovule which has undergone certain changes as a result of fertilization is called a *seed.* Under appropriate conditions the seed will germinate and produce a new plant. The new plant is not produced from the whole seed, but only from a part of it. This part is called the *embryo.* Germination consists in the growth and development of the embryo which pushes its way out of the *seed,* the root turning down and the stem turning up. Even in seeds which have not yet begun to germinate the embryo is divisible into three parts:—

1. Young root, called *radicle.*
2. Young stem, called *plumule.*
3. One or two seed-leaves, called *cotyledons.*

Each seed has sufficient food stored inside it to supply the needs of the embryo until the radicle has reached the soil. If this food is stored in the embryo (viz., in the cotyledonary part of it) the embryo is large and usually fills almost the whole space inside the seed-coat. On the contrary, if this food is not stored in the embryo, the latter is usually small, and occupies only a small portion of the space inside the seed-coat. The rest of the space is filled with food material (called *albumen*). The former kind is known as an *exalbuminous,* and the latter as an *albuminous* seed.

1. First examine the *bean-seed,* after previously soaking it for about 12 hours in water.

   a. Make a drawing of the bean, noting the black streak. How do you account for this mark?

   b. Remove the seed-coat. The remainder

is the embryo. Identify and draw its three component parts—the radicle, the plumule and the 2 cotyledons. (Compare with Fig. 5.)

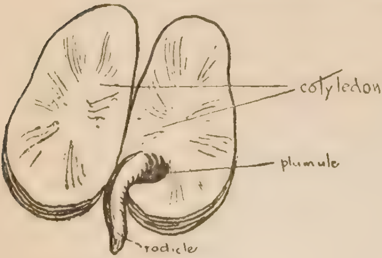


FIG. 5

Seed Coat of Bean removed and parts opened out.

c. Smear a drop of very weak iodine on the cotyledon. Notice that it turns bluish-black, showing that the food-material consists mainly of starch.

2. Next examine a large albuminous seed, *e.g.*, the "stone" of the date.

FIG. 6

a. The seed-coat in this case is a very thin and membranous covering on the "stone." Make a drawing of the "stone."

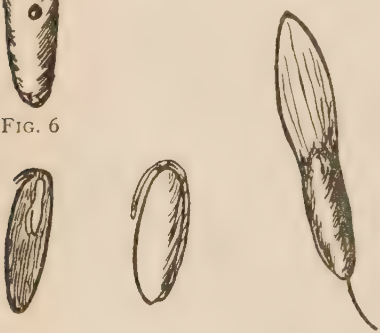


FIG. 7

A. Winged Fruit of Ash.
B. Same dissected out.
C. Embryo on a large scale.

b. Search the surface until a small round protuberance about half the size of an ordinary pin's head is seen (Fig. 6). Cut the "stone" across at this point and detach the embryo. Note size and shape, then draw on a large scale. Note that the embryo-food, viz., the "stone," is of a different nature to the food stored in the cotyledons of the bean. It consists of cellulose, not starch.

c. Take out the seed from a fully ripe *ash-*

fruit, and cutting it open, discover the small embryo that lies inside. Sketch the embryo *on a large scale*, using the pocket lens for the purpose. Identify the cotyledons, young root and young stem (Fig. 7).

d. Examine in the same way as many as possible of the following seeds, and compare with the above: *pea*, *lupin*, *cucumber*, *orange*, *lemon*, *shepherd's purse* and *almond*.

Note.—All those plants, the seeds of which possess two cotyledons, are grouped together under the term *Dicotyledons*.

V.—THE SEED (*continued*)

General Remarks (V).—In the preceding section we saw that the bean- and ash-seeds had 2 cotyledons. The seeds of a large number of plants, however, possess only one cotyledon. The latter plants are grouped together under the term *Monocotyledons*.

1. Examine a seed taken from any large flower in which the flower-parts are arranged in threes or sixes. Examples are, *lily*, *tulip*, *crocus*, *iris*, *gladiolus*, *narcissus*, etc.

   a. Ascertain whether the embryo is large or small.

   b. Note whether the seed has one or two cotyledons.

   c. Identify the other parts of the embryo and make drawings in illustration.

2. Examine a few samples of Indian corn (maize).

a. How do you account for its angular appearance?

b. Compare the two broad flat sides and note the difference between them. Make 2 drawings of the fruit, one to illustrate each of these two sides.

c. Cut the fruit into halves by passing the knife lengthwise through the middle of one of the broad flat sides. Refer to Fig. 8 for guidance and make a search for the embryo.

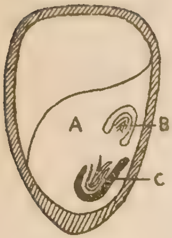


Fig 8

Longitudinal Section of Maize Grain.

A. Scutellum.
B. Plumule.
C. Radicle.

d. Make a careful drawing of the plumule and radicle.

e. Where is the embryo food stored, inside or outside the embryo?

f. Note that the embryo is covered by a layer of tissue which separates it from the rest of the seed. This is called the *scutellum* and is supposed to represent the cotyledon, for a structure similar to the cotyledons of other plants is wanting in the maize and its allies (Grass family).

VI.—GERMINATION (I)

General Remarks (VI).—When a seed is placed in a fairly warm and damp place germination begins. The conditions necessary for germination are:—

1. That the seed be a sound one.
2. That the temperature be within a certain range.
3. That the soil be not too dry or too wet.
4. Air.

Germination can best be observed by placing the seeds in damp sawdust or in bog-moss (Sphagnum), or if very small, on flannel or muslin stretched over a tumbler filled with water. If sawdust be used it must not be too wet, otherwise fungi are sure to attack the young plant, and not too dry, otherwise the seeds will not germinate.

1. Place half a dozen bean-seeds in water and leave them for 12 hours. Note the effect on the seeds.
2. Place these half dozen seeds in damp sawdust, and at same time place another half dozen, without having previously soaked in water, in another box of the same kind. Take out one of each kind every week and compare the rate of growth. Deduce from your results the part that water plays in germination.
3. Follow the germination of the bean-seed with great care, making careful drawings of the various stages. Plant a dozen seeds, take one out and sketch every 4 days. Compare with Fig. 9.

Note the following points and confirm them by your own observations.

1. The radicle is the first part of the embryo to emerge from the seed.
2. The plumule comes next. Note the direction taken by each.
3. The cotyledons in the bean remain underground.
4. The cotyledons lose their firm texture and gradually shrivel up as the plant grows bigger. Why is this?
5. After the roots have grown a certain length they begin to form branch roots. How is the plant thereby benefited?

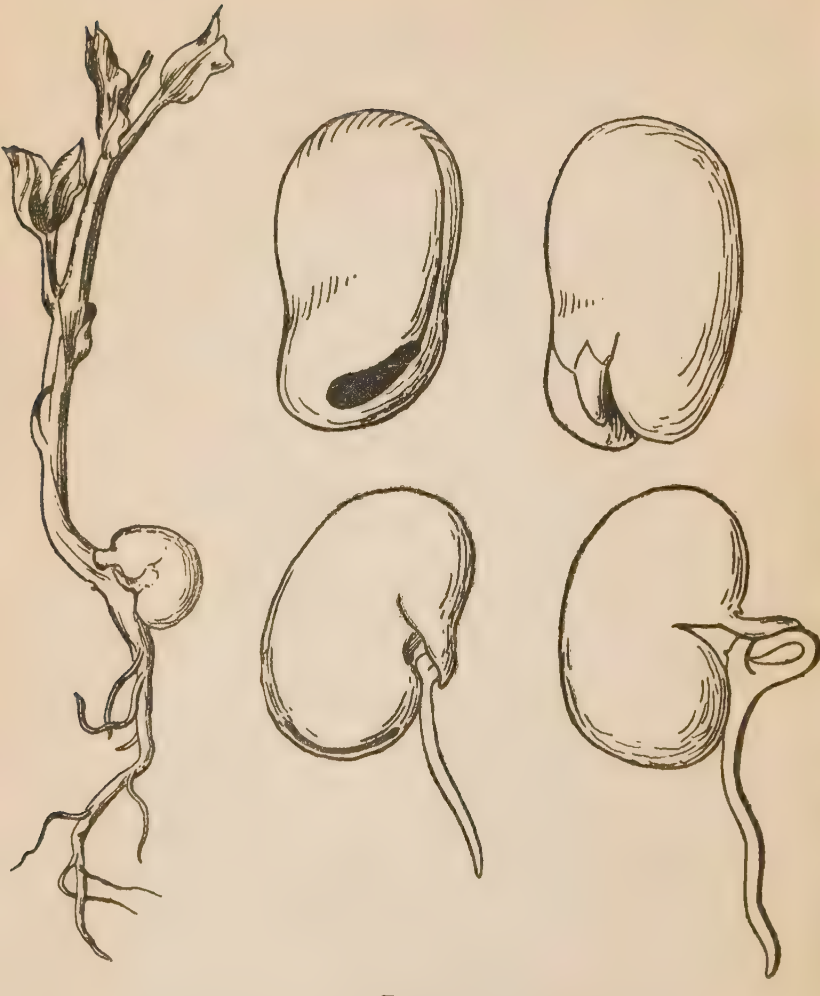


Fig. 9

Bean Seeds in various stages of Germination.

6. Near the end of each of the rootlets you will find a collection of root-hairs. Make a drawing of one of these root-branches, showing the distribution of the root-hairs.
7. The stem of the young plant forms leaves at different points on its surface. Note the shape and arrangement of these leaves.

Next plant, in the same way, a dozen *lupin* seeds, and follow the same procedure as in the case of the bean. Compare with Fig. 10 and note the following points.

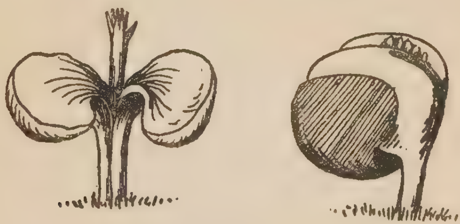


FIG. 10
Germination of Lupin. Two stages.

1. Do the cotyledons differ in their behaviour to those of the bean? If so, how?
2. Do the cotyledons shrivel and lose their firm texture?
3. Cotyledons are seed-*leaves*. Do you see any resemblance in these cotyledons to foliage-leaves?
4. Make careful sketches of the foliage-leaves as they appear, noting the way in which they are folded before they finally spread out.

Next germinate seeds of sunflower, cress, turnip and mustard, all of which are easily obtainable. Examine in exactly the same way, make sketches and note carefully any

B

differences you may find in the mode of germination. Note particularly—

1. The seed-coat. In some seeds it is carried up above the ground, in others it remains below.
2. The radicle. In some seeds it becomes the root of the plants, in others it is short-lived, the subsequent roots being formed as outgrowths from the young stem.
3. The plumule. See how the leaves are arranged on the stem.
4. The cotyledons. Do they function as foliage-leaves or do they remain underground? If the latter, do they turn green?

VII.—GERMINATION (II)

General Remarks (VII).—In the preceding section the germination only of Dicotyledons was investigated. In this section only Monocotyledons will be dealt with.

Germinate a few *onion*-seeds, noting and sketching the stages of germination. Pay attention to—

1. The long slender root.
2. The slight swelling at the top-end of the root. This is the stem.
3. The *single* cotyledon, which may be found inside the seed-coat. Note how this organ is attached, and also how it is arranged inside the seed-coat.
4. The *secondary* roots which arise from the base of the short stem.

Next germinate a few grains of Indian corn (maize), selecting a large variety for the purpose. They should

be kept in a warm room, otherwise growth will be very slow. Sketch seedlings of different ages and note the following:

1. The radicle comes out first, but its growth is very limited. Find out where the roots which appear later spring from.
2. Examine the base of a root and note the sheath out of which it appears to grow. The root arises from *inside* the plant and pushes its way to the outside. The sheath is composed of that part of the plant through which the root has pushed, on its way to the outside.
3. The *plumule* forms a tubular sheath, being at first closed at the tip, but later the tip opens and from the opening the first foliage leaf bursts through.
4. The tissue which envelops the embryo and which is supposed to represent the cotyledon does not leave the seed.
5. As the young plant grows, the tissue in which the food is stored grows more and more pulpy.

Seeds of wheat or barley should also be germinated. Sketch the stages in germination, noting how these plants differ from the maize. Though the same in essentials, there are several small differences in the course of germination.

VIII.—THE PHYSIOLOGY OF SEEDS AND SEEDLINGS (I)

General Remarks (VIII).—It must be constantly borne in mind that plants, like animals, are living organisms. The essential parts are built up of the same living matter, or

protoplasm as it is called. Consequently we find the same activities exhibited by a plant as by an animal. It takes in food as raw material, elaborates this into more and more complex materials, until finally protoplasm is formed. Again, *respiration* is just as essential to the plant as to the animal, because the plant is dependent on this process for its supply of energy: oxygen is taken in, this unites with the protoplasm, the latter then breaks down into simpler substances. We may compare the energy obtained by this means to the energy obtained by setting a light to gunpowder. The oxygen represents the light and the protoplasm the gunpowder. Some of the energy thus gained by the plant goes to raise its temperature, some to supply the energy which is needed for growth, for reproduction, for movement, etc. Some of the substances that are formed by the breaking down of protoplasm are useless and are usually thrown off in the form of gas (carbon dioxide), or if solid are sent to the deciduous parts of plants (bark, leaves, etc.). Others are useful and are made use of by the plant in a variety of ways. Thus some of them may be again used as food to build up protoplasm, others may be used to form cell-walls or colouring matters, or other substances that the plant requires for its growth. If more food is present than is required for immediate use the surplus is usually stored in some convenient form (*e.g.*, starch), so that it may be accessible when again required. Further, provision must be made for the next generation, and so, when seeds are being formed, a quantity of this reserve food is stored in them. It is this food which seedlings utilize until they are able to make their own food.

Practically all seeds contain food in the form of 2 or more of the following:—

Carbohydrates.—Compounds containing carbon, hydrogen, and oxygen, in which the last two are present in the same proportion as water. Examples of such foods are starch, cellulose, inulin and sugar.

Proteins.—Food bodies containing carbon, hydrogen, oxygen, nitrogen, sulphur, and in many cases phosphorus as well.

Oils.—Compounds which when dropped on glazed paper make it transparent. They contain carbon, hydrogen and oxygen, the last named being present in smaller proportion than in carbohydrates.

To recognize these classes of food-materials the following preliminary experiments should be undertaken.

1. Heat some dry starch in a test-tube. Water collects on the side of the tube, hence hydrogen and oxygen are present in starch, for water is composed of these elements. Prolong the heating and notice that the starch becomes a charred mass like charcoal, thus indicating the presence of carbon.
2. Powder some starch, place in water in a test-tube, and boil for some time. Add a few drops of a solution of iodine. Notice the blue colour that is formed. This is the commonest test for starch.
3. Pour a little of a solution of mercurous nitrate in nitric acid over a piece of bread. Note the red colour that is produced. This is a characteristic test for proteins.
4. Place some small pieces of bread in a test-tube and pour over them a strong solution of nitric acid.

Heat gently and note the deep yellow coloration of the bread. Add *carefully* a little ammonia and note the vivid orange colour which the bread now assumes. This is another characteristic test for proteins. Try this experiment also with almond seeds.

5. Another good test for protein solutions is the following:—Add strong solution of potash and then a drop of dilute copper sulphate. If proteins are present the liquid becomes violet in colour. By thoroughly shaking crushed almonds with water, and then filtering, a good solution for this test can be obtained.
6. Place a drop of olive oil on some blotting-paper and note if the stain differs from that produced by water.

IX.—THE PHYSIOLOGY OF SEEDS AND SEEDLINGS (II)

General Remarks (IX).—In all seeds under examination the nature of the reserve food should be determined. The following experiments indicate the method of examination that should be adopted.

1. Place a drop of dilute solution of iodine on the cut surface of the cotyledon of a bean-seed and demonstrate the presence of starch.
2. Do the same with a section of a wheat or barley grain. The greater portion of the cut surface will be seen to turn bluish-black, showing the presence of starch, but a layer near the outside

will be found to have taken on a brown colour, showing the absence of starch. Cut another section of the same kind and test this layer for proteins, as indicated in the preceding section.

3. Cut the inside part of a brazil nut with a heated knife. Note its obviously oily nature. Place small portions between blotting-paper and crush them between 2 flat stones. A greasy stain is left on the blotting-paper. Test in the same way, the seeds of the castor-oil, cress and others that appear to you to be of an oily nature.

Digestion of the Reserve Food.—The reserve food is never present in the seed in the form in which it is used up by the plant. It must be stored in a form insoluble in water. Why? The food is made digestible in exactly the same way as in the animal body, viz., by the secretion of digestive fluids (ferments).

Starch is changed into *sugar* by the action of the ferment *diastase*.

1. Test for sugar by means of *Fehling's solution.* Dissolve 35 grammes of copper sulphate in 200 c.c. of water. In another bottle dissolve 70 grammes of Rochelle salt in 200 c.c. of a 10% caustic potash solution. Keep both solutions in separate bottles. For this test mix equal volumes of the first solution, of the second solution and of water. Add some of the mixture to the juice of a grape, or a plum, or some other fruit. Also add some to cane—and other sugars. All except cane-sugar give a red precipitate at once: cane-sugar only after prolonged boiling.

2. Procure some extract of malt. This contains the

ferment *diastase*. Mix some of it with a paste made of flour and water. After a day or so try the sugar-test. The diastase in the malt extract will have converted the starch of the flour into sugar. All the starch found in seeds is changed in this way. A resting seed does not contain ferments of any kind; these are developed only when they are wanted, *i.e.*, just at the beginning of germination. The business of the maltster is to germinate barley grains up to the point when the maximum secretion of *diastase* has taken place. The young seedlings are then killed by heat, the product being known as *malt*.

3. *Proteins* are changed into soluble nitrogenous substances. The best known protein ferments are *pepsin* and *trypsin*, the latter being far more widely distributed in plants than the former.
4. *Oils* are changed by a ferment called *lipase* into *glycerine* and a *fatty acid*, both of which are soluble in water. Crush some castor-oil seeds and place some of the crushed mass in alcohol. Test with litmus-paper; the reaction is neutral. Do the same with castor-oil seeds that have begun to germinate. Test with blue litmus-paper and note the acid reaction.

X.—THE PHYSIOLOGY OF SEEDS AND SEEDLINGS (III)

General Remarks (X).—The results of the respiration of a number of people in a badly-ventilated room are well known. The room gets "stuffy" owing to the accumulation of carbon dioxide and the dearth of oxygen. Precisely the same results are obtained when a number of seeds are allowed to germinate in a small enclosed space.

The following experiments on the respiration of seeds should be made.

1. Half fill a wide-mouthed bottle with moistened peas. Insert a lighted match or taper for a moment inside, and notice that this makes no difference to the burning. Close the bottle, using a cork which has been dipped in paraffin-wax, or better, rimmed with plasticine. Perform the same experiment after 24 hours and notice that the match is immediately extinguished when now inserted into the bottle. As oxygen is necessary for combustion, what inference do you draw?
2. Next lower down into the bottle a small dish containing *lime-water*. In a very short time the surface becomes quite milky. Take the dish out and shake gently; the lime-water becomes milky throughout. Putting a short glass tube to your mouth blow through another portion of lime-water. This produces the same effect. Hence the gas given off by germinating seedlings

is the same as that given off by ourselves during respiration, viz., carbon dioxide.

It therefore follows that seedlings take in oxygen and give out carbon dioxide, the process being exactly the same as that which takes place during our own respiration.

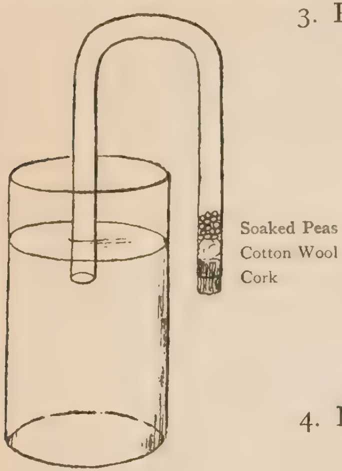


FIG. 11.—*See* Text.

3. Place a U-tube in a small jar, as shown in Fig. 11. One end of the U-tube is inserted in the jar, in which some lime-water has been placed. The other end is corked, and resting on the cork are a few soaked peas, which are kept in damp cotton-wool to prevent them drying up. Notice the effect of the germination of the peas on the lime-water.

4. Perform the same experiment, but instead of lime - water place a strong solution of caustic potash in the jar. Caustic potash is a strong solvent of carbon dioxide. Explain why the liquid rises in the U-tube.

5. Rig up the apparatus represented in Fig. 12.

Wide-mouthed jar with a well-fitting cork.

Muslin bag attached by a bent pin which is stuck on the under side of the cork. The bag is filled with peas and something to keep these moist, *e.g.*, bog-moss or small pieces of sponge.

Egg-cup containing a sponge which has been soaked in caustic potash solution.

Glass tube bent twice at right angles.
Jar containing water.

Set aside in a warm room and note the results. Why does the water gradually rise in the tube? It rises to a certain mark and then stops. Why? Remove the cork and insert a lighted taper in the bottle. What happens? And why?

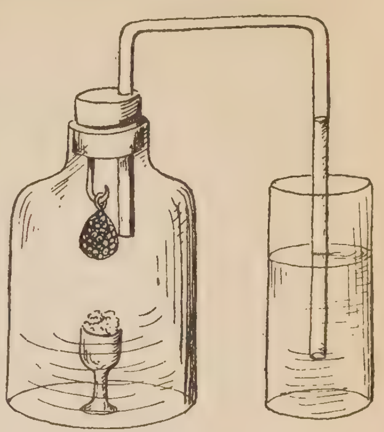


FIG. 12.—*See* Text.

6. Half fill a tumbler with soaked peas. Cover the tumbler with a piece of cardboard, and through a hole in the latter pass a thermometer down to the bottom of the tumbler. Follow the same procedure with another tumbler, only soak the seeds with a disinfectant instead of with water, thereby preventing both germination and putrefaction. After a day or two note the difference in temperature between the peas in the two tumblers. What causes the difference?

XI.—THE STEM (I)

General Remarks (XI).—It is obvious that the main functions of the stem of an ordinary plant are to support the leaves which it has produced and to serve as a means of communication between the roots and the leaves. The following experiments will help us to a closer view of the subject.

1. Place some fairly large bean-seedlings with their roots in water coloured with red ink. After an hour or so remove one from the water and cut thin transverse slices from different parts of the stem. Notice that the water has not risen uniformly, being found only in certain spots which form a disconnected ring in the slice. By cutting down instead of across the stem it will be found that the red colour is confined to a number of strands. Trace the course of some of these strands. They connect the root below with the leaves above. They are called *vascular bundles.*
2. Procure an old cabbage stalk and cut it across somewhere near the middle. Notice that the vascular bundles are more strongly developed than in the bean-seedling, forming a continuous compact ring (Fig. 13). The vascular bundles become more strongly developed as the plant becomes older.

   Examine the tissue on the surface. It has a different consistency to the tissues inside the stem, and is known as the *epidermis.* The tissue which is not included in the epidermis or the vascular bundles is known as the *fundamental tissue.*

3. Place a few drops of *phloroglucin* * on a section of the cabbage stalk and after allowing it to remain for a minute wash gently under the tap. The vascular ring is stained a bright red.
4. Trace the course of the vascular bundles from the stem into the leaf by cutting off from a herbaceous plant a bit of a stem with a bit of a leaf attached to it, and placing the piece in a dilute solution of potash. The softer parts disappear first, thus bringing the vascular bundles into prominence.
5. In the same manner trace the bundles from the stem into the root.

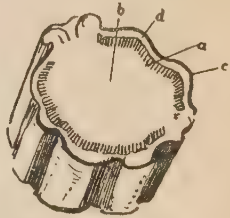


Fig 13 Slice of cabbage stalk

a = Ring composed of vascular bundles.
b = Soft inner tissue.
c = Skin (epidermis).
d = Soft tissue between *c* and *a*.
d and *b* together compose the fundamental tissue.

6. Scrape off the epidermis of a thick herbaceous stem, *e.g.*, sunflower or cucumber, and examine the tissue which lies immediately underneath with a hand lens. Scrape off a small portion of this under tissue, macerate as much as possible in a drop of water and endeavour to make out the shape of the cells. Sketch one or two on an enlarged scale. Notice that the epidermis is harder to cut through than the cells immediately

* This reagent is prepared as follows:—Dissolve some phloroglucin in methylated spirit, and gradually add strong hydrochloric acid till precipitation begins. The liquid is then ready for use.

underneath. The epidermis is therefore made of a tougher material. Does this benefit the plant?

XII.—THE STEM (II)

General Remarks (XII).—In a transverse section of a very young stem the bundles are arranged in the

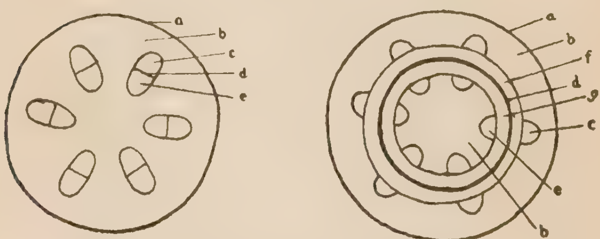


Fig 14 a. Fig 14 b

Diagrammatic Representation of Unthickened Dicotyledon Stem.

a = Epidermis.
b = Fundamental tissue.
c = First formed or primary bast.
d = Cambium.
e = First formed or primary wood.
f = Secondary bast (formed by cambium).
g = Secondary wood (,, ,,).

form of a discontinuous ring. Each vascular bundle is made up of three kinds of tissue, which have different functions to perform. They are known respectively as *wood* (nearer the centre), *bast* (nearer the outside), and between the two a thin line of tissue called the *cambium*. (*See* Fig. 14.) In dicotyledons the formation of new wood and bast is due to the power of growth possessed by the cambium, in virtue of which new cells are constantly being formed. Of these

the outer ones become bast cells and the inner ones wood cells, whilst a narrow line of cells between the new wood and new bast cells still retains the character and shape of cambium and never loses its power of forming new bast and wood cells so long as the plant is living. These changes are represented diagrammatically in Fig. 14*b*. The functions of wood and bast may be demonstrated by the following experiments.

1. Cut off portions of twigs from one or more of the commoner trees and compare the vascular bundles in the youngest part of the twig with those in the older portions of the twig. Make sketches to show these differences. See if you can identify the bast, and also the cortex (outer fundamental tissue), which lies between the bundles and the epidermis.

As the cambium is not active in winter, and as the wood which is formed in spring is different to that which is formed in late summer and autumn, each year's growth of wood is sharply marked off from that of the preceding and that of the succeeding year. This explains the succession of rings that are seen when a woody stem is cut through.

2. Examine a section prepared from the branch of any shrub or tree, and by counting the rings ascertain the age of the branch.
3. Cut off a willow twig in early summer. From the middle part of the twig remove a ring of bark about an inch wide. Remove also the soft tissue immediately underneath the bark, thus laying bare the hard wood. Place the twig in water, which must be changed every day. Notice the difference in behaviour of the buds below and above the cut portion. The part below the cut

portion suffers because the food supply which travels downwards through the bast has been cut off. Hence in the vascular bundles the food from the soil is conveyed upwards through the wood, whilst the food from the upper part is carried downwards through the bast.

Whilst most of the cells of the wood are devoid of contents, a certain proportion of them are living, *i.e.*, they contain protoplasm. In older trees the living cells of the central part of the wood lose their protoplasm. In this condition they contain less water than when in the living condition. The result is that the central part of the wood is different in appearance to the outer part of the wood in which these cells are still living. The central part is known as *heartwood* and the outer part as *sapwood*. Which kind of wood is preferred by the joiner? And why?

4. Examine the large blocks of wood that can be seen in any timber-yard and make out where the heartwood ends and the sapwood begins.

5. Obtain smoothly-planed blocks of the commoner kinds of wood and compare the appearances presented by the different kinds of wood. Notice whether the rings are closely set or wide apart. Notice particularly whether a number of lines running radially from the centre to the periphery are to be seen. These are the *medullary rays*. They serve partly to store reserve food, chiefly starch and oil, and partly to convey food material from the central to the peripheral parts of the plant. See if these rays

present any distinctive features which will enable you to recognize the commoner kinds of wood by their aid. Examine the oak in particular.

XIII.—THE STEM (III)

General Remarks (XIII).—Every *living* cell of the plant must be supplied not only with food and water but also with oxygen. The following experiments show how this is rendered possible.

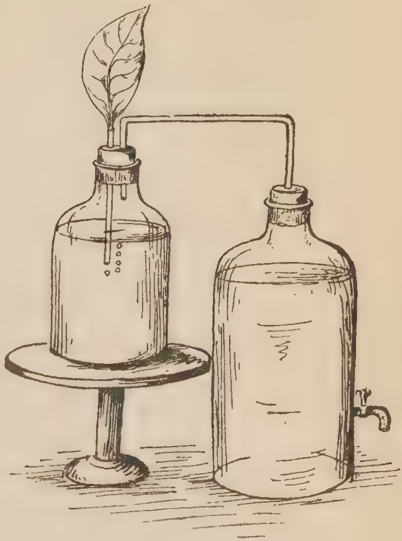


Fig. 15.—*See* Text.

1. Cut off any large leaf near the base of its stalk and insert the stalk through a hole in the cork stopper of a fairly large bottle (Fig. 15). Pour water into the bottle until the bottle is nearly full. Through another hole in the cork insert a glass tube and connect the latter with an aspirator.* As water is withdrawn from the bottle air passes into it from the end of the leaf-stalk. This

* The simplest kind of aspirator is a large bottle with a tap somewhere near the bottom (Fig. 15).

shows that air finds no difficulty in entering into the tissues of the leaf and down the stalk. There is therefore direct communication through the leaves, between the inside of the stem and the atmosphere.

2. Next cut a transverse section through any herbaceous stem, *e.g.*, sunflower, and examine through a microscope. Do the cells fill every corner? Is their shape such as to make this possible? The air spaces between the cells are known as *intercellular spaces*.

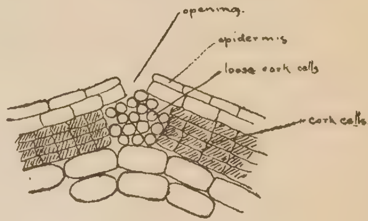
General Remarks (XIIIa).—Not only is air admitted through the leaves, but also direct through the stem. In very young stems there are openings similar to those in the leaf (which will be discussed later). In slightly older stems a ring of cork is formed inside the stem but near the surface. This would shut off the admission of air through the stem altogether, were it not that the cork cells beneath the openings are very loosely arranged, not being closely packed as in the other parts of the ring (Fig. 16).

3. Examine the outside of young branches of the beech or oak or sycamore. Notice that the surface of the bark is studded with a number of minute patches. Each patch has an opening which admits air into the stem. These patches are known as *lenticels*. Examine the lenticels of birch and note how they differ from those of the other trees. Make sketches to show how the general appearance of the stem is

affected by the shape and distribution of the lenticels.

Cork for commercial purposes is obtained from the *cork-oak*, which forms large quantities of it.

4. Examine a thin sheet of cork. Notice that it is punctured with a number of small holes. After the remarks just made about lenticels, the student should be able to deduce the method of formation of these small holes.



Diagramatic sketch of Lenticel

FIG. 16

5. Examine an ordinary cork stopper. Notice that the holes run across, not up and down. Why is the cork cut this way?

XIV.—THE STEM (IV)

GENERAL REMARKS (XIV).—In many plants the stem has become modified to perform functions other than those mentioned above. In some, the modification is so great that it is possible to know that they are stems only by certain characteristics which distinguish all stems, however much they may have become changed. All stems are not above the ground no more than are all roots under the ground. The chief characteristic by which all stems may be re-

cognized is the fact that they bear leaves and that in the axils of these leaves buds make their appearance. In many stem-modifications the leaves may also become greatly modified, but their leafy nature is still evident. In every such case the student should ascertain—

1. The proof of its stem nature.
2. The advantage to the plant of each particular modification.

The following types should be studied.

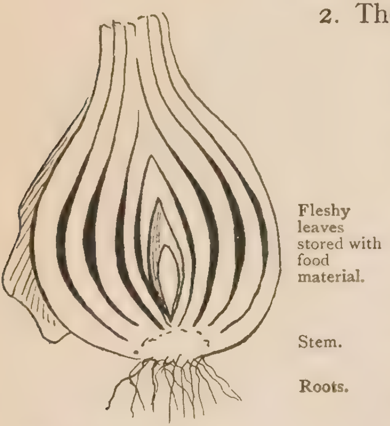


FIG. 17

Bulb.—Halve the bulb of an onion by cutting from top to bottom. Make a sketch of one of the cut portions. Note the large fleshy leaves which make up almost the whole of the bulb (Fig. 17). Note also the smallness of the stem (which is found at the base), as compared with the leaves.

Place another bulb in water and set it aside for a week or two to allow growth to take place. Where do the roots, which grow into the water, spring from? After the flowering shoot has appeared, ascertain that the latter springs from the axil of one of the leaves. How does this stem-modification aid the plant? Where is the food stored, in the stem or in the leaves?

When a flowering shoot has been formed a new bulb arises at its base inside the old one, which by this time has been deprived of most of its contents,

and still later forms a mere brownish shell covering the new bulb.

Corm.—A corm differs from a bulb in that, inasmuch as the food material is stored in the stem, this organ is very large and prominent, whilst the leaves which are so prominent in the bulb are here reduced to a few brown membranous scales covering the stem (Fig. 18). The directions given for the examination of the bulb apply equally to the examination of the corm. The corms of crocus are suitable for this purpose. Set a corm in water and allow the buds to develop. Notice how new corms are formed. Compare with Fig. 19.

FIG. 18
Corm of Crocus.

Stem Tuber.—This is a swollen portion of an underground stem. Examine the potato tuber. The "eyes" should be carefully examined. Each is a small outgrowth arising from a sunken pit. What happens to this outgrowth if the tuber be kept in a damp cellar? How would you ascertain that the tuber was a stem and not a root? Examine for starch. See if the "eyes" are more thickly placed at one end than at the other. Weigh a tuber and then place it in damp sawdust. Allow the "eyes" to sprout in a dark room. Weigh again after well-developed sprouts have issued from the tuber. The total weight of tuber and sprouts is now less than the weight of the tuber before it began to sprout. Why is this? Feel the tuber. What makes it now so much softer?

Rhizome.—A stem running more or less horizontally

FIG. 19
Development of Crocus Corm.
Three buds have developed and each has begun to form a new corm at its base.

under the ground is called a *rhizome.* Study the rhizomes of *couch-grass* or *iris* or *Solomon's-seal.* A number of leaves are sent up above ground every year. These die down later, the insertion of each leaf being marked by a scar on the rhizome. Each year the rhizome grows forward, thus occupying a fresh portion of soil.

Make a sketch of a typical rhizome showing—

1. In the case of stout rhizomes, the scars of the leaves of previous years. In the case of slender ones the rhizome itself may bear only scaly leaves, the green leaves being borne on aerial shoots which are developed from the rhizome.
2. The roots that are developed on the under side.

3. The nature of the branching (if any).

As branches become separated from the rest of the rhizome new plants are thereby produced.

How does this stem-modification benefit the plant?

Compare your sketch with Fig. 20.

Climbing Stems.—As plants obtain a part of their food from the air through the agency of the leaves, the advantage to a thin stem that cannot support itself by its own rigidity, of the power of climbing, is obvious. Examine a plant in which climbing is effected by the coiling of the stem round a vertical support. Make a sketch of a portion of such a plant, noting the following:

1. The direction of the coil. Supposing yourself looking down on the stem from above, see whether the coiling is taking place in a clockwise or an anti-clockwise fashion. Examine one or more of the following—bindweed, hop and scarlet-runner.
2. The behaviour of one of these plants when allowed to grow without meeting with a support.
3. The arrangement of leaves on the stem. Are they so placed that they catch the maximum amount of light?
4. The time taken by the tip of a young plant to complete a single revolution.
5. The exact behaviour of the tip when it meets with a support.

Runner.—A runner is a slender stem which grows along the ground, sending upwards here and there a cluster of leaves and flowers, and downwards a cluster of roots. Very good examples are the strawberry and creeping crowfoot. Make a sketch of a strawberry-runner. Notice that at various points leaves, flowers and roots are formed. From

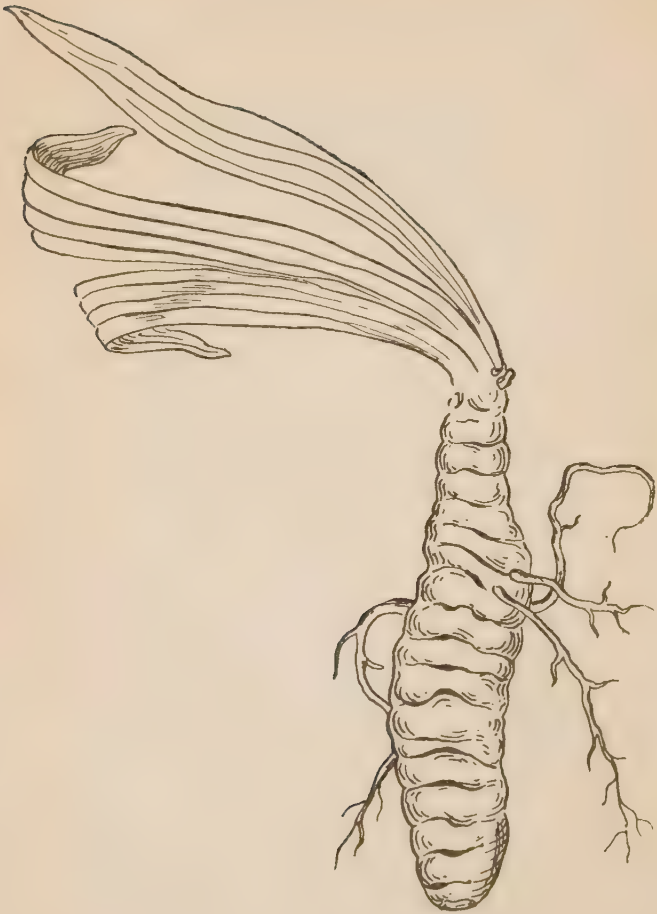


FIG. 20.—Rhizome of Iris.
The segmentation is caused by the scars of former leaves, which in this plant are almost completely circular.

each of these points a number of fresh runners are developed. How is the plant benefited by this stem-modification?

Examine the creeping crowfoot in the same manner. A short thick runner is called an *offset* (*e.g.*, house leek).

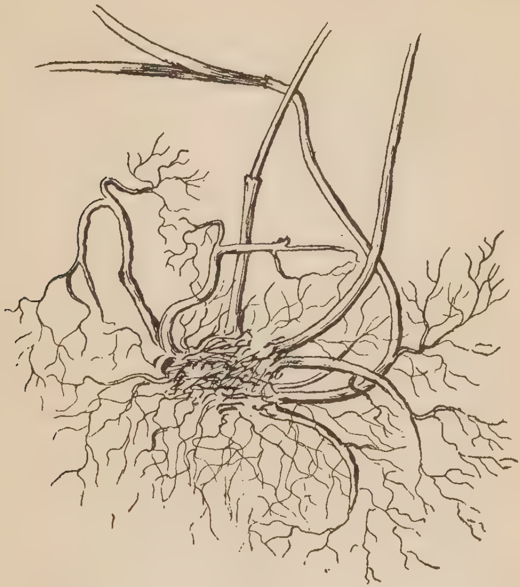


FIG. 21
Suckers of Grass Plant.

Sucker.—This is an underground branch, which arises below the soil and grows upward to the surface, forming leaves and flowers. How would you ascertain that the part which is underground is a stem and not a root? As most of the wild plants propagate themselves vegetatively by suckers, examples will not be difficult to find. (*See* Fig. 21.)

Explain why the hedges and fields assume a fresh, clean green colour in spring.

Stolon.—A stolon is a branch which grows downwards towards the earth, into which it penetrates. As the branch grows, forming new leaves and buds, the parts behind die off, so that complete separation is effected from the parent plants. Follow a downward growing branch of the bramble, and notice that it enters the earth.

XV.—BUDS

General Remarks (XV).—Buds arise from the outer surface of the stem, being usually formed in the axils of leaves (axillary buds), *i.e.*, in the space where the base of the leaf-stalk joins the stem. Buds are young branches which have not yet developed into twigs. Those seen on trees in winter have been formed too late in the season to permit of any further development until the following spring, for the conditions of moisture and temperature do not permit their growth during the winter. They burst into life once more in the following spring. A bud consists of a very short branch, bearing a number of leaves which, owing to the shortness of the stem, are very close together. In order to survive the winter, protection must be afforded from frost, micro-organisms, and particularly from evaporation of the water contained in the bud, for as the root absorbs little or no water from the soil during winter, any water lost by the buds in this way could not be replaced. The leaves therefore are very close together, being tightly pressed and overlapping. Not only so, but in almost all woody plants the buds are covered by special leaves (bud scales), which afford

ample protection. Some are hard and thick, others resinous, or corky, or hairy.

Buds are very useful as guides to the identification of trees in winter.

1. Examine first one of the large herbaceous buds known as Brussels sprouts. Note that there is, in this case no special covering in the form of scale-leaves, etc. Divide into halves by cutting from top to bottom. Make a careful sketch, indicating the manner in which the leaves fold over one another so as to afford mutual protection. Look in the axils of the leaves to see if any small buds are commencing to form. Notice the difference between the leaves at the apex of the stem, and those nearer the base. Next cut another sprout, but this time *across* the middle. Make a sketch to show the appearance of the sprout in transverse section.

FIG. 22
Section through Brussels Sprout

2. Examine the winter buds of beech, birch, oak, sycamore, horse-chestnut and ash. In each case proceed as follows:—

   (1) Make a sketch of the general appearance of the buds.

   (2) Note their colour, size and location.

   (3) Pick off the protective bud-scales, one by one, noting the way in which they fold over the enclosed foliage leaves. Are they hard or corky, or resinous or hairy, or very thin and membranous?

   (4) Pick off the foliage leaves one by one and note the manner in which they are arranged, so as to occupy as little space as possible. Are they arranged in pairs? How are they folded? Make sketches to illustrate these points.

   (5) Cut a thin transverse slice from the middle of the bud and make a drawing of the slice.

3. When the buds are opening, follow the various stages. This can best be done in spring and early summer. A large-leaved plant like the horse-chestnut is very suitable for this purpose, but others should be examined as well. Note particularly the unfolding of the leaves and the elongation of the stem. Examine the axils of the young unfolding leaves to see if any fresh buds are coming into existence.

4. Look backwards along the twig of any tree you are examining, and, by identifying the scars of the bud scales, find out the limits of this year's growth. Look still further backwards and see

FIG. 23

I. Horse-Chestnut, taken from country-grown trees.
II. ,, ,, town-grown tree. I. has grown in one year more than double amount grown by II. in seven years.
III. Poplar.
IV. Lilac.

a = buds, b = leaf-scars, c = scars of bud-scales.

if you can recognize how much the twig has grown during the last 2 or 3 years. In the twigs of most trees it is possible to ascertain each year's growth for several years back.

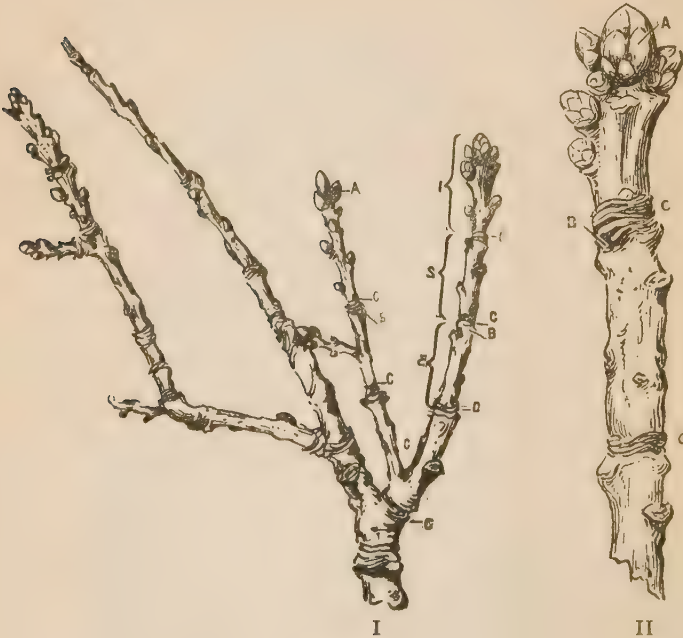


FIG. 24

I. Oak.
II. Same on larger scale lettering, as in Fig. 23.

5. Examine near the spot where a young twig joins on to the parent twig. Notice the scars. These are the scars left by the bud-scales after falling off.

Sketches similar to those in Figs. 23 and 24 should be made for several of the commoner trees.

Note.—The study of buds may be profitably extended when the fundamental points have been grasped. Thus, the extent of the present season's growth can be ascertained by finding the topmost bud-scale-scars (*c*). The distance between *c* and the top is the present season's growth. Search downward for the next group of bud-scale-scars, when last season's growth can be ascertained. The following problems may, for example, be undertaken.

1. To compare the rate of growth of horse-chestnuts which are growing under *different* conditions (*see* Fig. 23, I and II). Any other tree will do for this purpose, but horse-chestnut is eminently suitable. In this way the adaptability or otherwise of any particular soil for any particular plant can be ascertained.
2. To compare the rate of growth of the various trees which are growing under the *same* conditions, *e.g.*, in the same grove, and to find out which are best adapted for their surroundings.

XVI.—FOLIAGE LEAVES (I)

General Remarks (XVI).—Leaves are developed as lateral outgrowths of the stem. They are formed at the growing apex of twigs, so that the youngest leaves on any particular twig are those nearest the apex, whilst the oldest are those that are furthest away. Their chief function is to absorb carbon dioxide from the atmosphere. This gas (in solution) unites with water to form sugar. Now this process, which is called *carbon-assimilation*, cannot take place except in daylight. It is therefore evident that every plant will have its leaves so arranged that they will catch the maximum

amount of light, and will avoid any arrangement whereby some leaves, though getting the light themselves, prevent others from having access to it. The necessity for obtaining light explains the various expedients adopted by many plants for raising themselves above their neighbours. In studying leaves, therefore, their relation to light should be the first point under consideration.

1. Select a young branch from a tree which is bearing leaves. Carefully note the mode of arrangement of the last named. Sketch the branch and the leaves. Note how well the space is filled up by the leaves. (Compare with Fig. 25.) Do they hide one another from the light? Examples should be taken from several of the commoner trees, like the sycamore, beech, birch and oak.
2. Notice the angle which the leaves present to the light. The sun's apparent course in the heavens is from S.E. to S.W. Find out how the leaves of any particular tree arrange themselves with regard to the sun's course. In temperate climates the strongest light does not come from directly above.
3. Examine some plants that have been placed in the window to grow. What is the biological cause of their inclination towards the window? Plant some cress seedlings in a box, and place them as far away from the windows of a room as possible. Observe their inclination after a few days.
4. Examine and sketch the leaves of the daisy. Note that this arrangement is well adapted for ensuring that all the leaves receive an equal amount of light. Make a note of other plants

that have adopted this rosette formation of leaves. It is a very economical arrangement in the case of plants that can obtain the light even whilst spread on the ground, for they do not

FIG. 25
Showing how leaves spread themselves out to catch maximum amount of light.

need to waste energy in erecting and supporting a relatively large stem.

5. Examine and sketch the leaves of grasses. They grow in dense masses. This arrangement into long, thin, upward-reaching leaves is obviously the only one which enables the light to reach all the densely-massed leaves.
6. Examine and sketch the leaves of plants that grow in open places where there is little hin-

drance to the light reaching all, or almost all, of the leaves. Good instances are leaves of floating water-plants, and those of most large trees like the beech, lime, etc. The leaves of these trees tend to assume a round or oval shape. This is obviously the most economical way of arranging the green, soft tissue of the leaf about its supporting framework, the veins.

XVII.—FOLIAGE LEAVES (II)

General Remarks (XVII).—As the leaves are responsible for the carbon-assimilation of plants, it is evident that the greater their number and the larger their dimensions, the greater their capacity for making food for the plant. But the upkeep of the leaves is an expensive item, and it would be fatal to the plant if it formed a larger number of leaves than it could supply with the necessities of life, just as much as it would be for a community to employ, say, 1000 bakers to make bread when they had not the wherewithal to supply the bakers either with flour to make bread or with the necessities of life which they would require. The number of leaves will therefore depend on the " capital " of the plant. In all cases it may be taken for granted that the number and shape of the leaves will be such that the maximum amount of efficiency will be attained with the greatest amount of economy, for the struggle for existence will have driven to the wall, all those that have not been able to reach this standard. We may assume that in a very large number of cases it had become necessary to develop less of the green soft tissue of

leaves. The first stage in this encroachment is seen, for one type of leaf in Fig. 26, a2, and for another type in Fig. 26, b2. Compare these two with Fig. 26, a1, and

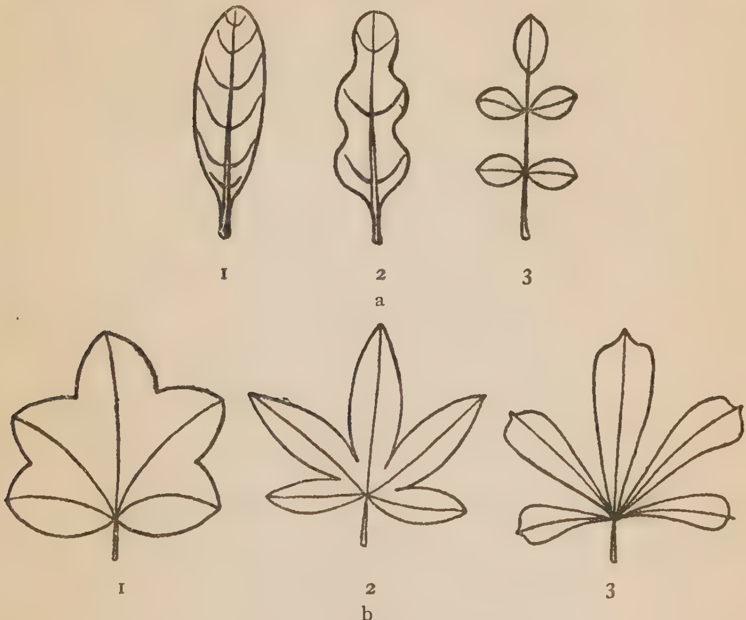


FIG. 26

Stages in reduction of leaf surface (diagrammatic)—
a. Feather-veined leaf.
b. Finger-veined leaf.

Fig. 26, b1, respectively. To study this point, we may divide all kinds of leaves into one or other of the following classes:

(1) Those with finger-shaped veins
(2) ,, feather-shaped ,,
(3) ,, parallel ,,

1. Collect about 40 different kinds of leaves and divide them into three groups in accordance with this classification. Then arrange them according to the encroachment that has taken place in the soft tissue. Two series of this kind are shown in Fig. 26. Where the encroachment has been so great that the component parts appear as separate leaflets (Fig. 26, a3, b3), the leaf is said to be *compound*. All others are denominated *simple*.
2. Examine the leaves of plants that grow in places where the leaves are thickly massed together, *e.g.*, hedges. Notice the frequency with which you meet plants, the leaves of which are broken up into very small segments, *e.g.*, herb-robert, wild chervil and its numerous umbelliferous relatives, milfoil, vetches, etc. Notice how this arrangement differs from that adopted by grasses. This is obviously a device to spread out the leaf surface between other plants in order to increase the chances of obtaining light. In some places the light would be hindered altogether by some obstacle, but it would only rarely happen that all the points occupied by the leaf segments would be completely shut off from the light.

Although its relation to light is by far the chief factor in determining the shape of a leaf, there are other cases in which other factors can be shown to have been the chief agents in moulding the shape of the leaf.

3. Examine the leaves of plants which grow in open uncultivated land. Notice the frequency with which prickly plants, *e.g.*, whin, thistle, hawthorn, blackthorn, etc., appear. The prickliness is

necessary to prevent the species from being stamped out by the depredations of browsing animals. Sketch a leaf of whin and of any kind of thistle to illustrate this characteristic.

4. Sketch the leaf of tropæolum. Notice that the leaf is slightly funnel-shaped. The light can have had nothing to do with bringing this shape into being. Note, however, that this shape is well adapted for preventing the leaf from becoming soaked with water, which would render it subject to the attacks of moulds and other micro-organisms. Note the large drop of water that is usually found, especially at early morning, at the bottom of the funnel.

Several other influences may be ascertained by carefully considering the leaf in relation to its environment. The following questions should be answered in examining a leaf.

1. How is it situated with regard to the light? Does it grow in places where its supply of light, owing to the crowding of its neighbours, is likely to be precarious?
2. Does it grow in places where it has habitually to resist high winds (*e.g.*, moorland plants)?
3. Is the soil in which it is growing, one that retains water readily?
4. Does the plant grow in a place where it is likely to need protection from animals or insects?
5. Does it grow on water, or under water, or in a marshy ground?

Other questions will suggest themselves to the student as practice is obtained in studying leaves from this point of view.

XVIII.—FOLIAGE LEAVES (III)

General Remarks (XVIIIa).—*Structure of the Leaf.*—An examination of the minute structure of the leaf shows 3 well-marked regions.

1. A skin covering both the upper and lower surfaces.
2. The veins which penetrate into every portion of the leaf.
3. Soft ground tissue (mesophyll) forming the bulk of the inside.

The skin or *epidermis* is to serve the purpose of protection and to guard against undue evaporation of water. It is perforated by a large number of minute holes, called *stomata* (singular stoma). The presence of these small pores permit free access of air into the inside of the leaf, where, as seen in Fig. 27, the cells are very loosely arranged. The epidermis is made up usually of a single layer of cells, which in the part facing the outside is composed of a tough substance called *cutin*, through which neither liquids nor gases can penetrate, so that all interchange with the outside air must be effected through the stomata.

1. Cut away a little of the skin of an iris leaf with a sharp knife, scraping off any of the under green tissue that may also be removed. Another way of obtaining the skin is to tear the leaf roughly across, when jagged pieces of epidermis will, in several cases, be seen projecting over the soft part and can easily be removed. Examine with a lens or, better still, under the microscope. Sketch what you see, noting the way in which the skin is marked off into areas, and also the

mode of arrangement of the stomata. Fig. 27 shows the cavity into which the stoma opens.

2. Boil a few leaves in potash solution, selecting for the purpose a thick leaf like the box or London pride. When the leaf is quite soft take it out of the potash, wash in water and cut off round the edge. It will now be found easy to scrape off a little of the middle soft tissue. Examine with a lens or under the microscope. Observe the size and shape of the cells and the small green bodies that are found in these cells.

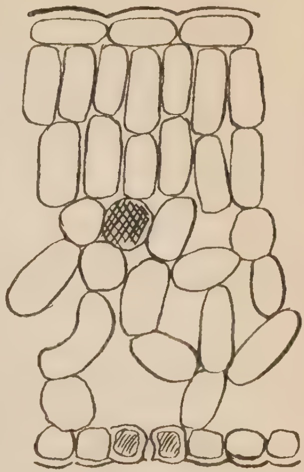


FIG. 27

Cross Section through Leaf (diagrammatic).

Note how well the plant is aerated.

It is inside the *chlorophyll corpuscles*, as these green bodies are called, that the carbon-assimilation — mentioned in Section XVI.—is conducted. It is to them also that the green colour of leaves and other parts of the plant is due. (If treated too long with

potash the leaves will become yellow in colour.)

3. Hold up to the light any fairly large thin leaf. Note first the prominent veins and then the little ones. Observe how they form an interlacing network which penetrates the whole length and breadth of the leaf. By boiling in caustic potash the soft parts disappear first. This makes the veins stand out more prominently. At the end of winter look out for the leaves of the preceding summer that have lain on the ground throughout the winter. You will find that they have been "reduced to a skeleton."

General Remarks (XVIIIb).—*Fall of the Leaf.*—The cause of the fall of the leaf in autumn is to be traced to the formation in autumn, of a layer of cork at the base of the leaf-stalk. This substance is impenetrable to water, so that the leaf soon dries up and falls off. The cork layer thus constitutes the scar, which marks the spot where the leaf was attached. In *evergreen* plants these cork layers are not formed.

4. Make a drawing of a portion of an old cabbage or Brussels sprout stalk. Observe the scars left by the leaves. Notice that the scars are different in colour to the rest of the surface of the stem. Notice that the difference in colouring is due to the presence of a layer of cork which covers the scars. Observe also that small mounds are seen above many of the scars. As these appear in the axils of the leaves, what would they become if they had been allowed to develop? (Fig. 28.)

XIX.—FOLIAGE LEAVES (IV)

General Remarks (XIXa).—*The Functions of Foliage Leaves.*—As already mentioned, the leaves are responsible for the carbon-assimilation of plants, the carbon being obtained from the carbon dioxide of the atmosphere. Now carbon dioxide is a gas, and neither gases nor solids can enter into the interior of plant cells. Hence the carbon dioxide must enter the cells in solution in water. Now, though the epidermis is impermeable to water, there is always a thin film of water on the unprotected surface of the cavities into which the stomata open. The carbon dioxide of the atmosphere is dissolved in this and then absorbed in solution into the cells. By means of the energy supplied by light, carbon dioxide and water are ultimately elaborated into *sugar*, which is a more complicated substance and consists of carbon, hydrogen and oxygen.

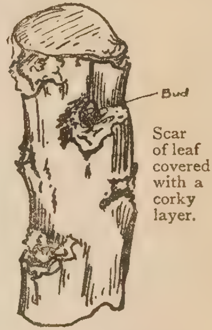


Fig. 28
Old Stalk of Brussels Sprout

To build up the living matter, however, more substances are needed. These are supplied by the soil and enter the plant, in solution, through the roots. There will, therefore, be a flow of food material downwards from the leaf, and upwards from the roots. When the leaf elaborates more sugar than it requires for immediate use, the surplus is changed into starch, in which form it is stored until again wanted, when it is once more converted back into sugar.

1. Pluck some leaves from a plant which has been standing in the sun all day. After boiling for some

time in water dissolve the chlorophyll by placing the leaves in alcohol, then when the greenness has disappeared wash in water and pour some iodine solution (iodine granules dissolved in potassium iodide) on the leaves. They turn blue, showing the presence of starch.

2. Perform the same experiment, only in the early part of the day cover up a portion of the leaf on both sides with thin slices of cork. Pluck off the leaf at the close of the day and treat as described in the preceding experiment. Notice that no starch reaction is given where the leaf was covered. What does this, therefore, prove with regard to the relation of light to carbon-assimilation?

We have seen in Experiment 1 of Section XIII. that the inside of a leaf offers abundant facilities for the passage of air, hence every cell containing chlorophyll corpuscles is supplied with all the carbon dioxide that it needs for assimilation.

General Remarks (XIXb).—The carbon-assimilation of plants, therefore, effects an extremely important interchange of gases. As a result of the respiration of animals, and of plants, the oxygen of the air is replaced by carbon-dioxide. The same result follows from all processes of combustion, such as the burning of coal, gas, etc. Carbon-assimilation brings about the very opposite change, as the poisonous carbon dioxide is absorbed and the life-giving oxygen set free.

3. Place some fresh water-plant in a jar of water and rig up the apparatus shown in Fig. 29. Place in the sunlight, and note the bubbles of gas which are

being given off in constant streams from the plant. Collect these bubbles and test for oxygen. (Oxygen rekindles a match, which has just been blown out, if the match be placed in it before the red glow dies out.) Elodea, the Canadian pond-weed, does very well for this purpose. This experiment gives better results if carbon dioxide be passed through the water before starting the experiment.

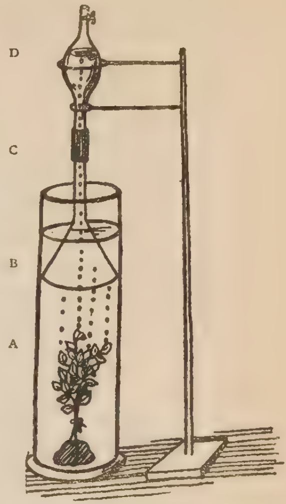


FIG. 29

A. Jar full of water, and containing also a bunch of Canadian pond-weed, kept in position by being tied to a small stone.
B. Glass funnel.
C. Small piece of india-rubber tubing holding B and D together.
D. Receiver, with stop-cock.

4. Procure a strip of the sensitive paper which is used to determine the proper exposure for photographic plates. Expose a little of this paper to the sun and note the rapidity with which it changes colour: expose another piece in a shady place and note that the change of colour is more gradual. Next strip off a portion of the epidermis from an iris or other leaf, and note how much longer the light takes to cause a change of colour when the epidermis is placed over the sensitive paper

during the exposure. The epidermis, therefore, protects the chlorophyll of the cells which are underneath from too direct an exposure to the light. Direct exposure to the light results in the decomposition of chlorophyll, which spoils it altogether for the work of assimilation.

5. Germinate some cress seedlings in the dark and note what happens. Is light necessary for the formation of chlorophyll? When you lift up a fairly large stone that has been lying on the grass for some time, what do you observe about the grass plants that are lying underneath the stone?

Hence from these experiments we conclude:

1. Light is necessary for the *formation* of chlorophyll.

2. Light is necessary for the *maintenance* of chlorophyll.

3. Very strong light destroys chlorophyll.

XX.—THE ROOT

General Remarks (XX).—A root is distinguished from a stem by the absence of buds and leaves, as also by having a different internal structure. The roots of most plants grow downwards into the soil, and function partly as organs of support, but chiefly as absorbents of food from the soil. This absorption does not take place over the whole surface, but is confined to a number of small hairs (*root-hairs*), which are found only near the tips of the roots. In some plants the radicle of the seed grows into the root of the adult plant, all other roots being branches of this main, or *tap*-root, as it is called. In others, the growth of the radicle is short-lived,

the root system of the plant being supplied by others (called *adventitious roots*), which spring from the base of the stem. It is important for our purpose to ascertain whether the roots feed near the surface or deeper down, for one of the chief reasons why certain plant groups are associated so frequently together is the fact that some feed near the surface and others deeper down.

1. Germinate a few beans, but in setting them allow them to rest in different positions, so that the radicles point in different directions—some down, others up, and so on. Observe that in all, the radicle, after further growth, grows down into the soil, even in those which had been placed so that the radicle pointed upwards. After the roots are well developed make a sketch of the root system. Wash the roots in water and carefully note the parts to which the soil clings most obstinately. A careful washing will reveal the root hairs.* Next observe the tip of one of the roots and see if you can make out a small protective cap (*root-cap*).
2. Plant some cress seeds in a shallow box (about an inch in depth), the bottom of which has been knocked out and replaced by a sieve, the meshes of which are just large enough to permit the young roots to push through. Observe carefully what happens after they have grown through. What explanation do you give for what has taken place?

* For most experiments on germination it will be found advisable to sow the seeds in damp sawdust or cocoa fibre, and not in soil, as it is difficult to extract them from the latter without tearing some of the parts.

3. Next plant some more seeds in the same or a similar box, only, in this case, place underneath the box, half an inch away, another box containing moist earth. Compare the behaviour of the roots, after they have emerged from the upper box, with what was observed in the preceding experiment.
4. To prove that the growth of the radicle cannot take place if oxygen be excluded, the following experiment may be made. Pin, or better sew, some bean seeds to a flat strip of cork as represented in Fig. 30. A reference to this figure and the explanation appended to it will explain the method of fitting up the apparatus for this experiment. The water is boiled to drive out the oxygen in solution. Compare the germination of the seeds above, with that of those below the water.
5. Pull up some grass plants, wash their roots and note how essentially differently arranged they are as compared with the roots of the bean. Note how well they are adapted for securing food from the surface of the soil.

XXI.—THE ROOT (*continued*)

General Remarks (XXIa).—*The Soil Exploration of the Root.*—Although the absorption of food from the soil is possible only by the root hairs, very little of the soil near the surface is left unexplored. The most important of the dissolved substances that are taken up are the *nitrates*, *sulphates* and *phosphates*, because nitrogen, sulphur and phosphorus

are constituents of protoplasm. A number of other substances are also necessary, because they belong to what may be called the machinery of the plant. Though they do not enter into the composition of protoplasm, still, without their co-operation protoplasm cannot be formed. Potash (or soda) and magnesium are necessary for carbon-assimilation; iron is necessary for the formation of chlorophyll; other essential elements are manganese and calcium. We have already mentioned that it is only in solution that substances can be absorbed by a plant. Of the substances in the soil that the plant requires, some are soluble in water, others are insoluble in water but soluble in water containing carbon dioxide in solution; a third group of substances is soluble only in water containing acid in solution.

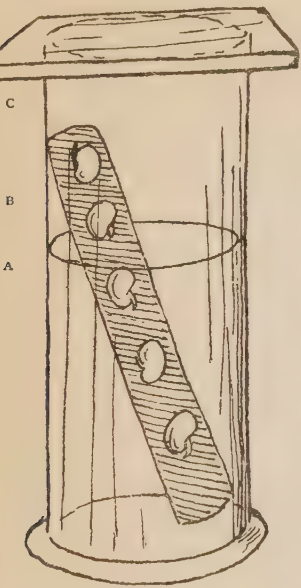


FIG. 30

A. Jar containing *boiled* water.
B. Flat strip of cork on which beans have been allowed to germinate until the radicle is about ½ inch long.
C. Firm cover, to prevent the water from being once more aerated by free contact with the atmosphere.

1. Allow some seeds of an easily-grown plant to germinate and then place them with their roots sticking into a solution made up as follows:—

Potassium nitrate	.	2 grammes
Sodium chloride	.	1 gramme
Calcium sulphate	.	1 ,,
Magnesium sulphate	.	1 ,,
Calcium phosphate	.	1 ,,
Iron chloride .	.	a drop or two
Water . .	.	2 litres

Note that growth takes place as well as if the plants had been placed in soil.

2. Notice what happens to the plant when one or other of the above constituents is left out from the culture-solution.
3. Grow seedlings with their roots in contact with moist blue litmus-paper, or grow them in the culture-solution, but adding to the other constituents a few drops of litmus, enough to give to the culture-solution a blue coloration. After growth has progressed somewhat note the gradual change in colour of the solution from blue to red. What does the plant liberate into the solution to effect this change?
4. As carbon dioxide turns lime-water milky show that roots give out carbon dioxide by germinating seeds in lime-water.

General Remarks (XXIb).—*Remarkable Way of obtaining Nitrogen.*—All the higher green plants obtain their nitrogen from the soil in the form of nitrates; in any other combination the nitrogen is not available. The free nitrogen of the atmosphere is likewise useless to them. But the planting of any one of the pea and bean family (Leguminosæ) actually enriches the soil so far as nitrogen is con-

cerned, in spite of the fact that a large amount of nitrogen is used up in the building of the plants. The explanation of this strange phenomenon is to be found in the fact that leguminous plants form an association for mutual benefit, with a certain class of bacteria which are able to assimilate nitrogen from the atmosphere. These micro-organisms change the nitrogen thus derived into a form suitable for absorption by the roots of the leguminous plants.

5. Pluck up the roots of as many examples of leguminous plants as you can procure (pea, bean, vetch, clover, etc.). Wash their roots and notice that in all small nodules are seen which are absent from the roots of other plants. The bacteria just mentioned are responsible for the formation of these nodules.

After what has just been stated the student will see the reason for the *rotation of crops* that is followed by agriculturists. Farmers do not plant, say, wheat in the same piece of ground for two successive years. Instead, they usually plant some member of the Leguminosæ on a piece of ground from which they had cropped wheat in the preceding season.

XXII.—FRUITS

General Remarks (XXIIa).—A fruit is that part of the plant which holds the seeds. If only the ovary contributes to the formation of the fruit, the latter is termed a *True Fruit*; if other parts contribute as well it is called a *False Fruit*. In examining a fruit we may therefore treat it as an ovary and inquire into the following points:

1. The number of cavities it possesses.

2. The number and arrangement of seeds in the cavity or cavities.
3. Whether derived from a superior or from an inferior ovary.

The fruit-coat is known as the *pericarp* [distinguish from the seed-coat or *testa*].

Other points to note are the following:

4. The nature of the pericarp, whether soft or hard, thin or thick, strong or weak, etc.
5. The mode in which the seeds are liberated from the pericarp.
6. Method employed to carry the seeds away from the plant. It is not advantageous for a plant to have its own seeds growing up in large numbers around it, for its own food supply is thereby endangered, as naturally the needs of the seedling and of the parent are precisely the same in this respect.
7. Means of protection, if any, against depredations of browsing animals.

1. Examine the *gooseberry* or *grape* or *tomato* or *currant*. These are all examples of *berries*, *i.e.*, fruits in which the pericarp is wholly succulent. Cut across the fruit and ascertain the number of cavities, arrangement of seeds, etc. How are the seeds liberated?
2. Examine the *cherry* or *plum* or *damson*. The seed is inside the "stone." The pericarp is partly hard ("stone") and partly soft. Such fruits are called *drupes*.
3. Fruits in which the pericarp is wholly hard are called *nuts*. Examine any of the common nuts in the manner indicated above.

4. Compare these fruits with the fruit of the *whin*, or of the *pea*, or of the *poppy*, in all of which the seeds are liberated through slits or pores in the pericarp.

General Remarks (XXIIb).—*Dispersal of Seed.*—The number of varieties in the modes of dispersal is very large. See if there is any structure in connection with the fruit or seed, the presence of which would facilitate the removal of the seed from the parent plant. The following are the chief methods:

A. By the development of hairy structures.
B. By the development of flat expansions.
(*A* and *B*:) So as to be caught up by the wind.

C. By the development of succulent pericarp, as an invitation to animals to feed on these fruits.

D. By the development of prickly hairs, so as to make animals their unconscious or unwilling carriers.

1. Examine the *dandelion* fruit. Each dandelion is a *collection* of flowers. Each flower forms a fruit. Notice particularly that a hairy appendage constitutes part of the fruit. Sketch a single fruit, noting carefully whether the surface of the fruit is smooth or sculptured in some way. In which direction do the small processes on the outside of the pericarp point? Of what advantage would this be, to the fruit, when it reaches the ground? [Note that it is the fruit and not the seed which is attached to the hairy appendage. The latter is derived from the calyx, which in this flower is persistent.]

2. Compare with the dandelion, other fruits of a similar nature, *e.g.*, groundsel, coltsfoot, etc.
3. Examine next the fruit of a *willow* or of a *willow-herb.* The dispersal is effected in the same way as the above, only note that the hairy appendages are derived from the seeds. Compare carefully with above fruits. Sketch a seed on a large scale, using the pocket lens for the examination of the hairs. How are the seeds liberated?

XXIII.—FRUITS (*continued*)

General Remarks (XXIIIa).—*Dispersal of Seed* (continued).—The formation of flattened expansions of the pericarp is confined to large fruits and is usually found only in trees which grow to a large height. Examples are the sycamore, ash and elm.

1. Make a sketch of the " keys " of a sycamore. Note that the flat expansion is derived from the pericarp. Verify this fact by cutting open the rounded basal part and discovering the seed.*
2. Examine in the same way the fruits of the ash and the elm. In each case pick out the seed and verify the fact that the winged expansion is derived from the pericarp.

Inasmuch as the embryo is the really important part of a fruit, there must be some protection for it in the case of those fruits that lay themselves out to be eaten by animals. Consequently it will be found that in all such fruits there is a hard

* The " keys" of the sycamore form a more acute angle than do those of the maple, which are inclined at an angle of almost 180° to each other.

covering round the embryo. This is either supplied by the seed coat or by the pericarp. In other cases again, as in date, the food stored in the seed is of a hard nature.

3. Examine again as many succulent fruits as you can find—grape, apricot, plum, gooseberry, melon, etc.—and ascertain in each case the source of embryo protection.
4. Collect as many prickly fruits as possible. Examples are robin-run-the-hedge, burdock, goose-grass and water-avens. Ascertain, by means of a pocket lens, what it is in each case that causes these fruits to attach themselves to our clothes, or to the fleece or fur of animals, with so much ease. Make a sketch of each of these fruits on a large scale.
5. Fruits which split open to liberate the seed should next be studied. With very few exceptions such fruits are not succulent. The mode of dehiscence is very varied, though for the same species, and in many cases for the same order, it is constant.

   a. Compare the mode of splitting of the whin fruit with that of the peony or marsh-marigold. See whether these plants split along one side only, or whether two sides split open The type to which the whin fruit belongs is called a *legume;* the peony fruit is an example of a *follicle.*

   b. A completely different type is exhibited by the poppy fruit. The seed escapes through small holes at the top of the fruit. Make a sketch of the fruit showing these holes. Are the long stalks of the poppy rigid or pliant? If the

latter, how would this help the seed to escape from the fruit?

c. Next examine and sketch the fruits of the primrose, stitchwort and any other fruits of this kind that you come across. In each case investigate very carefully the manner in which the seeds are liberated.

General Remarks (XXIIIb).—*Means of Protection against Browsing Animals.*—In investigating this subject attention should be directed to the following:

a. Do the fruits possess an unpleasant taste or distasteful smell?

b. Has the plant any prickly formations that would make the acquirement of the seed a matter of difficulty to a browsing animal?

Examine the fruits of plants that grow in open places, such as a common or a piece of waste ground, *e.g.*:

A. Cow-parsnip.—Observe the streaks of black that are characteristic of the fruit of this plant. Its unpleasant taste and smell are due to the oily matter of which these streaks are composed.

B. Whin.—Observe the spiny branches and leaves.

C. Woundwort.—Note the obnoxious smell of the whole plant.

D. Thistle.—Examine the fruit of any one of the various thistles and note how efficiently the prickles protect the seeds.

XXIV.—FALSE FRUITS AND OTHER ABNORMAL CASES

General Remarks (XXIVa).—We have already mentioned the manner in which false fruits differ from true ones (*see* General Remarks XXIIa). In the majority of such fruits we find that the "falseness" is brought about by the participation of the top portion of the flower-stalk in the formation of the fruit.

1. Examine the red "hip" of the *wild rose*. It consists of a kind of cup partially closed at the top. Inside the cup the carpels are located, whilst round its rim will be found the remains of the calyx, corolla and stamens. The cup is therefore the *calyx tube*, which has become enlarged and coloured. Remember that the rose is a perigynous flower.
2. Sketch also the *apple*. Cut across the fruit and sketch the appearance presented in section. The apple is of the same nature as the "hip" of the rose, only that the modification of the calyx tube has gone further; it has become much larger, and in growing inwards has fused with the walls of the five free carpels which are placed inside the cup. In the cross section note the 5 cavities, each containing a single seed. The glistening membranous lining of the cavity is the wall of the ovary, to which the encroaching calyx tube has become fused (Fig. 31).
3. Examine next the *strawberry* fruit. Here the end of the flower stalk, which bears the floral parts, has

expanded into a globular form and become succulent. That being the case, are the small structures that cover the strawberry, seeds or carpels?

4. It will be a useful exercise to compare the raspberry or bramble, which are true fruits, with the strawberry, and to ascertain, in the case of these fruits, the part of the plant which has become succulent.

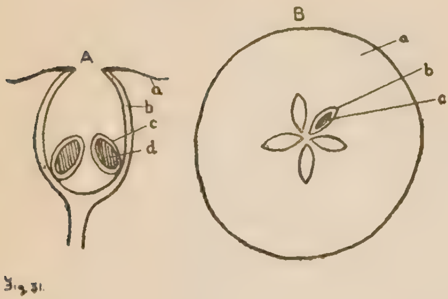


FIG. 31

A. Diagrammatic section of "hip" of rose—
a = calyx,
b = calyx-tube (red portion of fruit),
c = wall of carpel—the true pericarp,
d = seed.

B. Diagrammatic cross-section of apple—
a = succulent calyx tube,
b = wall of carpel—the true pericarp,
c = seed.

It will be remembered that in a true fruit the wall of the carpel alone forms the outer covering of the seeds.

GENERAL REMARKS (XXIVB).—A few of the common fruits show somewhat remarkable methods of dehiscence and form a class apart from the others. A noteworthy case is that of the wild geranium, and another, the various members of the cow-parsnip family (Umbelliferæ).

1. *Wild Geraniums.*—The pistil consists of five fused carpels. These come apart in the fruiting stage, remaining attached to the stalk only at one point near the top. Identify the 5 carpels after they have come apart. How many seeds are there in

each of them? Examine the most advanced stages to find out how the seeds are liberated.

2. *Cow-parsnip and Allies.*—This is of the same kind as the above, only there are here only two carpels. Note and sketch the mode of attachment to the stalk.

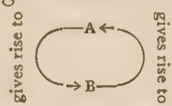
XXV.—CLASSIFICATION OF PLANTS

General Remarks (XXV).—Plants are divided into 5 groups, viz.:

1. *Algæ.*—These are the lowest forms of vegetable life. Members of this group form the green scum that is found in many streams and ponds. They are all water-plants, and many are so minute that high powers of the microscope are necessary to make them visible. On the other hand, their highest members, viz., the seaweeds, have reached a fairly high stage of development. They are all characterized by the possession of the green colouring matter *chlorophyll*, though in some cases this is masked by the presence of other colouring matters.

2. *Fungi.*—These are lowly forms, consisting of very fine threads, which in some phases of their life-history become coherent to form solid tissues (*e.g.*, the mushroom). There is no distinction of stem, root and leaf; they possess no colouring matter, and all thrive by feeding on either living or dead organic matter (parasites and saprophytes respectively). The plants of this group are the great scavengers of Nature.

3. *Mosses and Liverworts.*—Among these plants we meet a differentiation into stem, root and leaf, though the structures of these tissues are very simple compared with the similar tissues of the higher plants. There is a very well-marked *alternation* in the life-history of these plants, *i.e.*, before the life-cycle is complete, two generations must be passed through: thus the generation A does not give rise to the next generation A direct, but instead, to the generation B, and it is the latter that gives rise to the next A generation.



One of the generations is *asexual*, *i.e.*, its reproductive bodies are capable of germinating without fertilization, and the other is *sexual*, *i.e.*, its reproductive bodies cannot germinate without fertilization. Its reproductive bodies are therefore of 2 kinds. The one which fertilizes (male), and the one which is fertilized (female). Hence the alternation is between the sexual and the asexual generations.

4. *Ferns.*—The stems, roots and leaves have a more complicated structure. The various tissues are more highly specialized in their functions. Many of these plants attain to the dimensions of trees. There is a very well-marked *alternation of generations*. As compared with the mosses and liverworts their outstanding characteristic is the very marked development of one of these generations, viz., the *Asexual Generation.*

5. *Flowering Plants.*—In these the structure of the various tissues are still more complicated. As compared with the lower plants, we find, for the first time, that the reproductive parts are definitely arranged to form flowers.

Examination of an Alga.—We can take the common brown seaweed called *fucus* as our type, though this is much higher than the vast majority of the members of this group.

1. Examine the mode of branching of the plant and make a rough sketch of its general appearance.
2. Note the slimy nature of the plant. It is made up of a large number of interweaving threads. The walls of these threads are very slimy in composition. Cut a thin section and examine under the microscope. The apparent distinction of tissue is due to the fact that at and near the surface the threads are packed much closer together than they are towards the middle. Make a sketch.
3. See if the specimen has any contrivance which would enable it to float in water. If so, sketch carefully.
4. How is the seaweed attached? Is there any evidence to show that the organ of attachment performs any other function? Compare it with the root of any of the higher plants that you have examined.
5. The ends of the branches bear the reproductive parts and have consequently a structure different to the rest of the plant. Examine and sketch one of these ends. Note its " spotted " appearance. Squeeze it slightly, when you will notice that minute particles of slime exude from the

minute pore which is placed in the centre of each "spot." A section across this part of the branch will show that each pore leads into a cavity. This cavity is known as the *conceptacle.* With the aid of Fig. 32 try to identify the following structures inside the conceptacle.

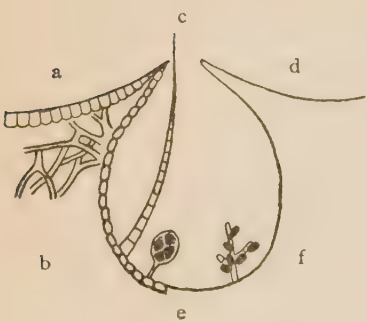


FIG. 32

Diagrammatic representation of conceptacle of fucus—

a. Outside part composed of threads tightly packed together;
b. Same as (a) only threads are more loosely packed;
c. Wall of conceptacle, like (a) in consistency;
d. Loose threads, arising from inside conceptacle and with their free ends projecting through opening;
e. Oogonium;
f. Cluster of antheridia.

(1) Long threads, some of which project through the pore into the outside.

(2) Round bodies on stalks. These are the female organs and are called *oogonia.* Each oogonium contains 8 *oospheres.*

(3) Small club-shaped male organs called antheridia. These are borne on very small-branched threads, which arise from the walls of the conceptacle.

Each antheridium contains thousands of extremely minute bodies called *spermatozoids.* The oogonia (female) and antheridia (male) are thrust out of the conceptacle into the surrounding water. The spermatozoids and oospheres are then liberated. The former swim towards the latter, surrounding them by the hundreds. Eventually one spermatozoid penetrates into the interior of the oosphere.

The latter is thus fertilized, and later grows into a new fucus plant.

By allowing freshly gathered seaweed to dry for a day or so, and then squeezing the reproductive branches, small drops of slimy liquid oozes out of the pores of the conceptacles. A microscopical examination of these drops will often show the presence of the spermatozoids. They are very small and must be examined with the high power.

XXVI.—THE FUNGI

General Remarks (XXVIa).—The fungi form a large class, with widely-different members. The *moulds* are excellent examples of a very common type. When articles of food, *e.g.*, puddings, jam, bread, etc., are set aside in a damp cupboard, the surface of these substances soon becomes covered with a felt of very fine white threads, which later assume a green or black colour. These are *moulds*.

1. Place a few prunes in a pot containing water and boil until the water is perceptibly coloured. Strain off the water and harden with gelatine (about 10 grammes to every 100 c.c. of water). Allow some of this jelly to harden on the surface of a plate and leave it exposed to the air for a day or two. Examine when the surface is covered with a number of spots, or *colonies* as they are called. These will be of two kinds, viz., either *fluffy*, with a rough outline, or *non-fluffy*, with a smooth outline. The former are moulds, the latter bacteria.
2. Detach a colony of mould, place on a glass slide and examine carefully. Note that it is white in colour and consists, microscopically, of a number

of very minute threads (called *hyphæ*), all radiating from a common centre. Observe and sketch a small part, showing the mode of branching, the cross-walls, and any other point that strikes your notice.

3. Next examine again after an interval of another 2 days. The moulds will now probably have partially turned green (*Penicillium glaucum*) or black (*Aspergillus niger*), or may have remained white (*Mucor mucedo*). Examine microscopically and note that the greenness or blackness is caused by the development of thousands of small roundish reproductive bodies called *spores*. Make a farther examination of these spores, with the aid of Fig. 33, and try to determine if one of the very common species, whose reproductive parts are described in the explanation appended to Fig. 33, has fallen into your plate.

General Remarks (XXVIb).—We may take the *mushroom* as our second type. What is commonly called the mushroom is in reality only the organ of fructification of the mushroom plant. The remainder consists of very fine threads, which branch and interweave in the earth. They are, in fact, exactly the same as those of the moulds, but they differ in that they do not appear above ground, except to form the fructification. At certain periods of the year these hyphæ grow together so closely that a small, roundish, solid body results. This appears above the ground and is the young mushroom fructification (Fig. 34, I). The hyphæ still continue to grow, though banded so closely together, with the result that a fairly large body, somewhat like a pear

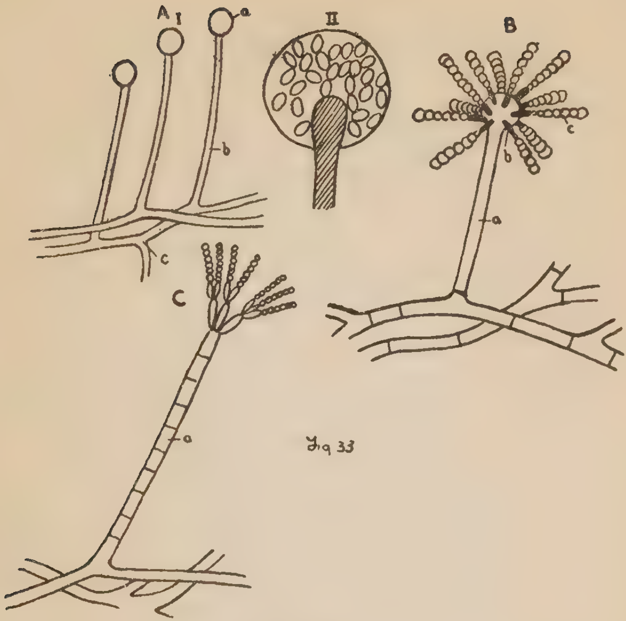


FIG. 33

Diagrammatic representation of the reproductive bodies of different moulds.

A. Mucor mucedo (white mould)—

I*a*. Globular expansion at end of stalk *b*, which rises vertically upwards from the hyphæ *c*.

II*a*. On a larger scale, showing enclosed *spores*.

B. Eurotium (or Aspergillus) glaucus. Reproductive parts—

a. Stalk expanded at the top into a globular structure, on which small rods (*b*) are developed. On each rod (*b*) a single row of spores (*c*) is formed.

C. Penicillium glaucum (green mould)—

a. Spore bearer, at apex of which a number of rods are formed. Each rod bears at the top 2 or 3 smaller rods. Each of these smaller rods carries a row of spores. Each spore is green in colour.

in structure, is developed. In this body a circular cavity is formed (Fig. 34, II*a*), which becomes deeper and wider as the young mushroom grows (Fig. 34, III*a*). Next, from the ceiling of this cavity, a number of radially-arranged screens are developed (Fig. 34, IV*b*), which grow downwards into the cavity. By this time the cavity has extended so much that the partition (Fig. 34, IV*c*) is very thin. Ultimately it is ruptured and the screens, which are the familiar "gills" of the mushroom, are exposed to view. On the gills are developed small, oval reproductive bodies (basidiospores) (Fig. 34, V and VI), which, on germination, develop into a new mushroom plant.

1. Procure a few mushrooms, selecting small specimens as well as those of average size. Make a sketch of a fully-developed specimen. Make another sketch to show the form and arrangement of the gills. Notice the fringe which circles the stalk. In view of what you know concerning the development of the mushroom, how do you suppose this fringe has arisen?
2. Make rough drawings of mushrooms in various stages of development, so as to bring out the changes of shape which characterize this development.
3. Scrape a little from the surface of a gill of a mushroom which has not begun to turn black in colour. Examine under the microscope and note the very small oval bodies (Fig. 34, V and VI) which you will find.
4. Scrape off a *very small* portion of any part of the mushroom, and placing in a drop of water, with a couple of needles, break up the portion into as tiny fragments as you can. Examine these under

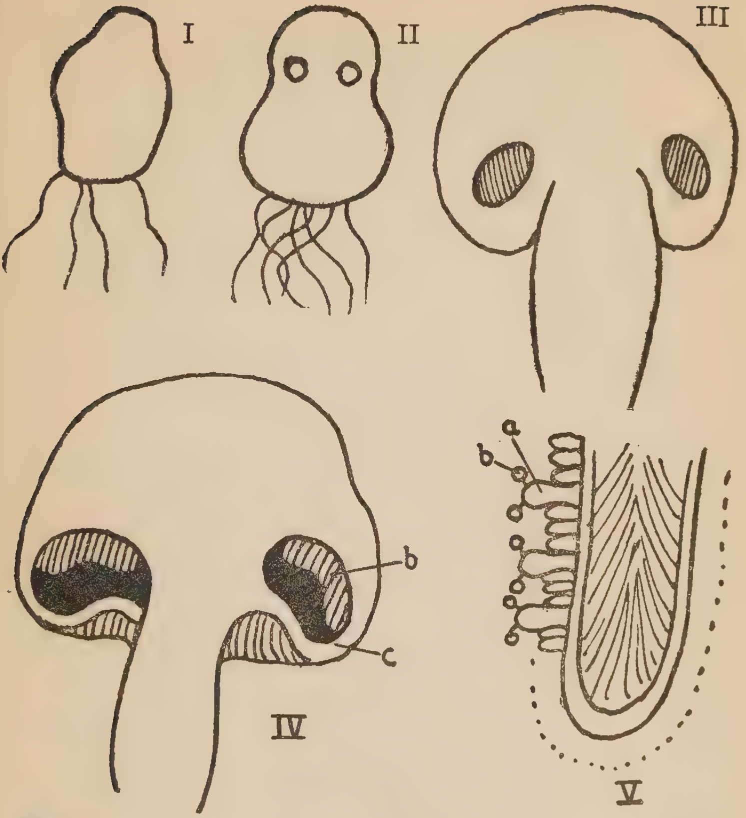


FIG. 34

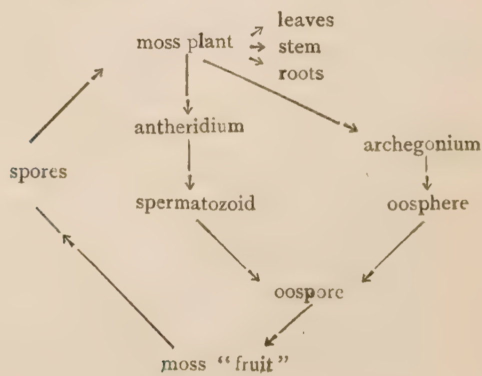
the microscope and observe that the mushroom is made up by the banding together of a large number of tiny threads, viz., the hyphæ similar to those observed in the examination of the mould.

XXVII.—THE MOSSES AND FERNS

General Remarks (XXVIIa). — Mosses may be gathered at any period of the year, but it is essential to study them when they are in " fruit " (Fig. 35). The term " fruit " is really a misnomer, as there is no comparison between the fruits that we discussed in the earlier sections and these that we are now about to study.

1. Sketch a single plant, showing leaves, stem and roots, then sketch a very small part of the stem with one or two leaves attached to it. Note the absence of buds in the axils of the leaves. Note the extreme simplicity of the leaf-structure. How are the veins of the leaf arranged?

The life-history of a moss can be best gathered by a reference to the following diagram:—



The archegonia are small flask-like structures (Fig. 36) that appear at certain times of the year at the top of the plant. Each contains a single round oosphere in the body of the flask (Fig. 36). The antheridia are also small structures that appear at the same time and place. They are club-like in shape (Fig. 37) and each contains thousands of very minute bodies called spermatozoids. The spermatozoid (Fig. 38) is composed of naked protoplasm, part of which is spun out into two long vibratile filaments called cilia. When ejected out of the antheridium the lashing of the cilia causes the propulsion of the spermatozoid, which is thus enabled to swim towards the archegonium. [It must be borne in mind that the spermatozoids are only able to move when submerged in water, but they are so small that they are relatively in deep water after a shower of rain.]

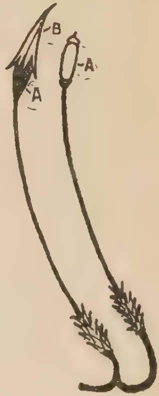


FIG. 35

Diagrammatic representation of Moss—

A. Capsule containing spores.

B. Cap or calyptra, belonging originally to the upper part of the archegonium. This is separated from the rest of the archegonium by the pressure of the growing "fruit," and is carried up as a cap on the top of the latter.

Fertilization is brought about by the union of the spermatozoid (male element) with the oosphere (female element). The fused product is called an *oospore*. This develops into the "fruit" (Fig. 35). Inside the "fruit" are a number of small, round or oval reproductive bodies called *spores*. When the spore germinates it produces a new moss-plant and so the life-cycle is completed.

2. Examine the "fruit." Note its mode of attach-

ment to the remainder of the moss-plant. Sketch the *capsule* at the top, and then remove a few of the *spores* that are found inside it. Examine under the microscope.

FIG. 36
Archegonium of Moss.

3. Examine the capsule in as many stages of development as possible, and see if you can make out the mechanism by means of which the spores are liberated from this body. Remove the cap which usually sits on the top of the capsule. When the spores are ripe the cap falls off and the upper part of the capsule comes off in the form of a lid.

FIG. 37
Antheridium.

GENERAL REMARKS (XXVIIB).—The life-history of the fern is more complicated than that of the moss. It can be represented schematically in the same way as that of the moss, only instead of "moss-plant" write "prothallium," and instead of "moss-fruit" write "fern-plant." Further, the prothallium does not consist of stem, root and leaves, but of a flat green body. We may therefore write the life-history as follows:—

prothallium ↓ antheridium ↓ spermatozoids ↓ oospore
prothallium ↘ archegonium ↓ oosphere ↓ oospore
oospore ↙ fern plant ↖ spores ↗ prothallium

1. Procure some prothallia from a gardener. They are often to be found on the earth of flower-pots. They are each about $\frac{1}{6}$-inch long and as much broad. Sketch one carefully, noting its shape, its flatness, its colour and its method of attachment to the earth. (*See* Fig. 39.)

FIG. 38
Spermatozoid.

2. Examine the under side of the prothallium through a microscope. Try to identify small globular protuberances (the antheridia) and the long necks of the archegonia. The oospheres of the latter are sunk in the tissue of the prothallium inside a cavity into which the necks of the archegonia lead.

3. Make a careful examination of either common bracken or male fern, noting the following:—

(1) The shape of the leaves or fronds, as they are more commonly called.

(2) The peculiar way in which the young leaves are rolled up.

(3) The underground stem. This kind of stem, a thick, horizontally-growing, underground stem, is called a *rhizome*. In the bracken the elongated, straggling rhizome branches at intervals. The branching is really lateral, but appears

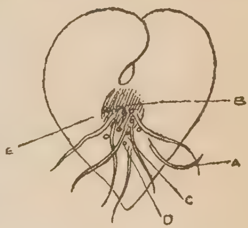


FIG. 39
Prothallium of Fern. Under side shown uppermost—
A. Rhizoids attacking prothallium to soil,
B. Cushion bearing archegonia,
C. ,, ,, antheridia,
D. Antheridium,
E Archegonia.

as if the rhizome had divided into 2 equal parts. One leaf comes up from the ground from each of the branches, and it appears in the third year of its development. The leaf-stalk divides and so the appearance of a cluster of leaves is presented.

(4) Wash a bit of a rhizome thoroughly and then make out the scars of the leaves of the preceding seasons. Also see if these scars show little spots indicating the places where the veins of the leaf entered the stem.

(5) Note the large number of strong roots that the rhizome sends down into the earth.

(6) How does the rhizome differ in appearance, etc., from the ordinary aerial stem? Can you see any gain to the plant from adopting this type of stem? Consider the question from the point of view of the food supply.

(7) Cut across the rhizome and note the difference between its consistency and that of the ordinary aerial stem. Is it of a woody nature? Examine the vascular strands that run through the rhizome, making a rough sketch of the same.

XXVIII.—FERN (*continued*). PINE

General Remarks (XXVIIIa).—We have seen that the prothallium of the fern "corresponds" to the moss-plant, because each produces the sexual reproductive parts, viz., the antheridia and the archegonia. In the same way the fern-plant "corresponds" to the moss-fruit, because both produce spores.

1. Remove some bracken or male-fern leaves, which show whitish or brownish structures on the back. Examine these latter carefully. Is there any relation between the structures on the back of the leaf and the veins? You will find that there are a large number of stalked globular bodies. (*See* Fig. 40.) Identify by microscopic examination the *stalk*, the *annulus*, the thin wall and the con-

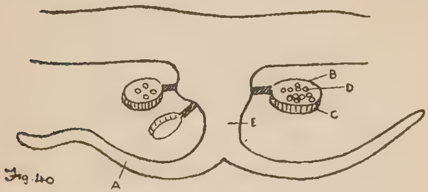


FIG. 40

Section through sorus of leaf of male fern—
A. Indusium, C. Annulus,
B. Sporangium, D. Spores,
E. Stalk.

(A *sorus* is the name given to a colony of sporangia and protective covering under which they are collected.)

tained *spores*. The stalked oval body is called a *sporangium*. The annulus straightens out as the sporangium dries, thus bursting the sporangium and liberating the spores.

2. Use the lens to ascertain whether the sporangia are, in any way, protected. The variety in the shape of this protective organ is one of the chief points that is made use of in the classification of ferns.

General Remarks (XXVIIIb).—The pine is a representative of the lower group of flowering plants, viz., the Gymnosperms. These plants are far more highly developed than the ferns, showing more specialized structures, and are especially distinguished from them by the possession of flowers.

1. Examine a twig containing leaves of the Scotch fir. Note that the leaves are arranged in pairs. A closer examination will show that each pair is inserted on a very short branch—called a dwarf branch. Two kinds of branches are produced by this plant:—

   a. Elongated branches, bearing only brown scale-leaves.

   b. Dwarf branches, each bearing a pair of long green leaves.

2. Examine the leaf. Note the needle shape. Plants living in high altitudes, exposed to storms and having only a poor supply of water at the best, find it necessary to diminish their leaf-surface, so as to avoid losing the supply of water already present in the plant. This is best done by making the leaf-surface as small as possible. The pine has been very successful in this respect.

3. Grip a few twigs, then smell your hands and note the odour of resin that emanates. This substance protects the plant from the attacks of fungi and other pests.

4. Cut across a branch that is about an inch thick, smooth down the surface and examine the cut portion. Notice that the branch is woody and that the wood is arranged in the form of con-

centric rings. There are as many rings as there are years to the age of the branch. The reason for the appearance of these rings is that the wood formed at the close of the season, viz., in autumn, has thicker walls and smaller cavities than the cells of the wood formed in the following spring. A ring marks the transition from one kind of wood to the other.

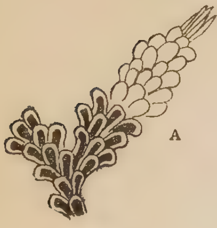


FIG. 41

Male flowers of Pine—
A. Collection of cones, each cone consisting of a number of flowers, each flower being made up of one stamen.

5. Examine next the pine flowers. These are *unisexual*, *i.e.*, the stamens are not found in the same flower as the carpels. Look out in May for small yellow clusters at the base of the shoot of the present season. Each cluster is a cone of male flowers. Identify by reference to Fig. 41. Each flower consists just of one stamen.

Remove a flower and compare with Fig. 42, in which three of these flowers very much enlarged, are shown. The whole flower, in this case, consists of a single stamen.

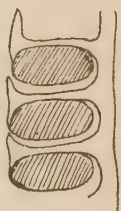


FIG. 42

Longitudinal section of portion of male cone. Shaded part is pollen sac.

6. Remove a few of the pollen grains from a stamen and examine under the microscope. Note and sketch its winged appearance. You will understand the use of this when you consider that pollination in the case of this plant is effected by the wind.

7. Next, about the middle of May, look out for the young female cones of the pine. They are, at this time, small roundish structures. Each cone consists of a number of stout scales arranged spirally round a stout axis. Remove one of these scales and identify the 2 ovules that are placed on its upper surface.
8. Next examine one of the old cones of the former season, some of which are to be seen still adherent to the tree. How are the seeds liberated from the cone? Is there anything in the general appearance of the seed to suggest its method of dispersal?

XXIX.—NUTRITION OF PLANTS

General Remarks (XXIX). — Revise the general remarks of Section XXI. before beginning this section. The chief steps in the nutrition of green plants can be represented as follows:—

Carbon-Assimilation (undertaken only by green plants, and by them only in daylight) (Refer to Section XVI.)

carbon dioxide (CO_2) → carbohydrate (sugar) ← water (H_2O); carbohydrate (sugar) → O

carbohydrate (sugar) (C.H.O.)

↓

← nitrates from soil to supply nitrogen (N.)
← sulphates from soil to supply sulphur (S.)
← phosphates from soil to supply phosphorus (P.)

↓

proteins (C.H.O.N.S.P.)

↓

Respiration (carried on by all living plants at all times) (Refer to Section VIII.)

proteins → protoplasm ← O

protoplasm → carbon dioxide (CO_2)

1. As all plants consist of cells, the water (containing the food in solution) must have the capacity of being able to pass through cell-walls.

   Fill a small bottle with golden syrup, cover the mouth with a bit of pig's bladder, then immerse completely in a beakerful of water. After an hour or two observe that the syrup has gone out of the bottle and that the water has entered it. The bladder corresponds to the cell-wall, the 2 liquids to the liquids inside and outside the cell respectively.
2. Place some green algæ in alcohol and observe after 2 days. The plants are colourless. How did the chlorophyll leave the cell?
3. Slice off a bit from the end of a long potato so as to make it stand on end, then gouge out a cavity beginning from the other end until the walls are about ¼-inch thick. Place the potato standing in a dish of water, and into the cavity pour some 5% sugar solution coloured with red ink. See that the level of the sugar is not lower than that of the water. Observe what happens and give an explanation.
4. As the veins of the leaf are the conductors of the food formed by the leaf, make a minute study of the veins of any leaf. If possible examine a decayed leaf. Examine the hedges in early winter for decayed leaves. Very often leaves which have altogether decayed, except for the skeletons, may be seen. These are particularly suitable for observation. Notice how thoroughly the veins penetrate into every portion of the leaf.

XXX.—NUTRITION OF PLANTS (*continued*)

General Remarks (XXXa). — *Transpiration.* — The water taken in by the root is sucked up and travels right up the plant to the leaves, where it escapes through the stomata. The food is abstracted from the water on its way up the plant. This stream passing through the plant is called the *transpiration-current.*

1. Make a 5% solution of cobalt chloride. Soak in it some filter paper, and then allow the latter to dry. It should be blue in colour. This paper changes colour in the presence of water vapour. Place a thin leaf between two cobalt papers. What happens? See if the change of colour takes place more rapidly on one side of the leaf than the other. The stomata, out of which the transpiration current is thrown off as vapour, are practically all placed on the under side of the leaf. Would this account for the fact that one side shows more change of colour than the other?
2. Fix a long-stalked leaf through a hole in a card and then dip the stalk in a tumbler of water, the card resting on the rim of the tumbler. Invert another tumbler over the leaf. Ascertain if any water vapour condenses on the surface of the latter tumbler. If so, where has it come from? After passing the stalk of the leaf through the hole in the card, it will be necessary to place some vaseline round the hole, to be certain that the condensed vapour on the inverted tumbler has

not come direct from the water in the other tumbler.

3. Dip the stalk of any leaf with a thin blade and a fairly long stalk into a bottle of red ink. Note what happens.

4. Take off a thin strip from the surface of the under side of a leaf and examine microscopically for the stomata (Fig. 43). The escape of the water vapour is effected through these pores. (The strip can be obtained either by cutting a slice with a razor, or better by tearing the leaf across with the hands and picking out a suitable bit from the jagged edges of the torn part.)

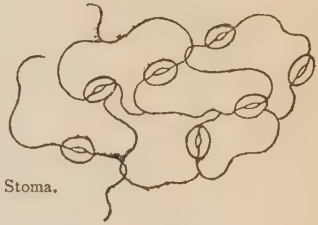


FIG. 43

Microscopic appearance of thin strip of skin of under side of leaf.

GENERAL REMARKS (XXXB).—*The Aeration of Plants.*—Every living cell must be supplied with oxygen, otherwise respiration cannot take place. The stomata are the open doors of the leaf. Inside each stoma is a cavity (Fig. 27), and starting from each cavity minute channels penetrate every part of the plant where there are living cells. In the case of plants which live under water these respiratory cavities are very large, and it will be found that without exception all water-plants are abundantly supplied with them. In the case of those plants which form bark the lenticels prevent the air from being shut out, as the cork cells

at these points are loose and round, so there is plenty of room for the air to pass in and out.

1. Rig up again the apparatus represented in Fig. 15. Exhaust the air by running the water out of the tap. Why do air-bubbles come out of the leaf-stalk, and where have they come from? Does this experiment show that air has a free circulation through the plant?
2. Dip a rhododendron or laurel leaf into very hot water in a tumbler. Notice the escape of air bubbles. Do they appear on the upper or under surface, or both? What explanation can you give of what you have observed?
3. Select a twig showing prominent lenticels. Peel off a bit of the bark and cut a thin section across one of the lenticels. Examine under microscope. Identify the loose cork cells.

XXXI.—THE "IRRITABILITY" OF PLANTS

General Remarks (XXXI).—The power of response of plants to external stimuli is known as *Irritability*.

Some parts of plants move *towards* the light, others away from it (heliotropism). Again the direction of growth is also affected by gravity (geotropism), by water (hydrotropism), by the presence of certain chemical substances (chemiotropism) and so on.

Plants respond to external stimuli only if certain conditions are fulfilled. These are:—

1. Adequate supply of water, food and oxygen.
2. Sufficient warmth.

1. Plant some cress seeds in a box containing moist sawdust and allow them to germinate at the end of a room furthest away from the window. Notice the direction of growth. Is this directive movement of the plant such that the leaves are brought into better positions for receiving the light?
2. Examine any group of plants growing in the window of a house. Do they bend towards or away from the window?
3. Place a few cress seedlings in a muslin bag, and let their roots grow through the holes in the muslin. Suspend the bag in a moist chamber, *e.g.*, a tumbler with a little water at the bottom. Set near the window. Cover the tumbler with a black cloth, but leave a slit open on the side towards the window. Observe the direction of growth of the roots.
4. Many leaves droop at night. Examine first during the day and again towards evening, the leaves of the clover, and of the wood sorrel. Note and sketch the different appearances presented by the leaves.
5. In the same manner, the flowers of the daisy, the red campion, the dandelion and others may be observed to close at night.
6. Note the effect of a rise of temperature, on a

bright morning, on the flowers of the tulip and crocus, causing the flowers to open out. Observe the same flowers closing again when the temperature falls.

7. After a seed has been allowed to germinate till its root is about ½ inch long, place it in such a position that its root points upward. Notice what happens to the young root and stem during their further growth.

XXXII.—STORAGE OF FOOD

General Remarks (XXXII).—*Storage of Food.*—We may roughly classify food into (*a*) non-nitrogenous and (*b*) nitrogenous. The non-nitrogenous food may be stored as *starch*, or as *oil*, or as sugar, or in some cases as *cellulose*. The nitrogenous food which is built up from raw materials, supplied both from the leaf and from the soil, is usually stored up as masses of *protein*. (Proteins are complicated organic food materials containing carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus.)

When again required by the plant the reserve materials are changed by digestive fluids (called ferments) into forms that the plants can assimilate. Each particular food has its own particular ferment, which has no effect on other kinds of food. Starch is usually stored in seeds, and in underground stems, *e.g.*, tubers, rhizomes, bulbs and corms. In the last-named, certain organs called *amyloplasts*, have the power of converting the sugar derived from the leaves into the insoluble starch.

1. Examine the cut surface of the fruit of any cereal or of any tuber or other underground stem and stain with iodine. Notice the intense blue-black reaction, showing the presence of starch. This reaction is best done by cutting a very thin slice, placing it in a drop of water, under the microscope, and then adding gradually a little iodine to the water. When examined under the microscope the distinctive blue colour will be easily seen.

2. Examine a few grains of starch under the microscope and compare with Fig. 45. Notice the curious stratification due to the deposition of starch, when the grain is formed, alternately in denser and more watery layers.

FIG. 45
Starch grain.

3. Obtain a small quantity of the very cheapest cocoa you can obtain and test for starch, which is the usual adulterant in such cocoas.

*4. Obtain some castor-oil seeds from a chemist's shop and examine a very thin section under the microscope. See if you can identify the oil globules that form the chief part of the storage food of this seed.

*5. Next cut a very thin section of the "stone" of a date, which is the seed of this plant. Test for cellulose by means of a mixture of iodine and sulphuric

* The section need not be more than about 1 sq. mm. in area, but it must be extremely thin. Do not attempt to cut big pieces. It usually results in spoiling the razor and in a sacrifice of the thinness.

acid, which causes cellulose to assume a blue colour.

6. Cover up a leaf of a plant in such a way that the whole of the leaf is in complete darkness. After 24 hours cut off this leaf, dissolve the green matter in alcohol and then soak in a solution of weak iodine (dissolved in potassium iodide). The leaf does not turn blue, thus showing the absence of starch. Do the same with a leaf (from the same plant) which has not been covered up. The leaf gives a good starch reaction with iodine. Hence a darkened leaf uses up its starch and cannot make more because deprived of light. What has become of the starch, and why should it be wanted? What process has been stopped by covering up the leaf?
7. Sugar is found in the succulent tissues of many plants, *e.g.*, sugar-cane, beet, onion, and apple. (*See* Appendix and Section IX.) Test small portions for sugar.

XXXIII.—SOILS

General Remarks (XXXIII).—Soils may be *light* or *heavy*. A *sandy* or *gravelly* soil is called light, because easy to work; a *clayey* soil is called heavy, because difficult to work.

Every soil is composed of particles of different sizes; in a clayey soil, very minute particles tend to predominate, whilst in the others there is a large percentage of comparatively large particles. Now the greater the proportion of very minute particles in a soil, the greater the amount of water

that can be retained by it, consequently a clayey soil can retain a good deal more water than the other kinds. This characteristic of clay soils is, however, not advantageous to vegetable growth, because the water sucked into the soil fills up the spaces between the soil-particles, which would otherwise be filled with air, and this air is necessary for the respiration of roots and other underground parts of plants. The operations of tillage are mainly directed towards breaking up the clayey part of a soil so as to introduce more air between the particles.

1. Dig a hole in the ground and observe the change in the character of the soil as you dig deeper. The soil near the surface is loose or friable; lower down the particles get bigger and are mixed with some stones. Then lower still there are more and more stones, and if you dig deep enough you will reach the solid rock. Soil is mainly formed by the breaking down of the materials of the underlying rock, the chief agency in this action being water holding carbon dioxide in solution. Dead animal and vegetable matter (humus) is formed on the surface. This is distributed in the soil by earth-worms and other creatures, and so a mixture is obtained favourable for plant life.
2. Weigh out 50 grammes of a soil, place in water contained in a beaker, stir, and then pour the mixture on top of a 2 millimetre sieve, collecting what passes through, in another beaker. Pour some more water through this sieve, so as to be certain that none that can pass through a 2 millimetre sieve has been left behind. Collect and weigh

the material left behind on sieve. Next pass the remainder of soil containing water, through a 1 millimetre sieve, and collect in same way, and then do the same through a ½ millimetre sieve.

Part retained by 2 mm. sieve = coarse gravel.
" " " 1 " " = gravel.
" " " ½ " " = sand.

Add up weights of these three; difference between sum total of weights and 50 grammes = *clay*. Try this experiment with various kinds of soils.

3. Place the same quantity of a dry clayey and of a dry sandy soil each in a funnel, and pass through each, the same quantity of water. See whether the same amount comes through.
4. Some soils contain chalk (carbonate of lime). Test this by adding some acid (strong vinegar will do) to a small quantity of soil. If chalk is present, bubbles of gas will be formed.

XXXIV.—WATER-PLANTS

General Remarks (XXXIVa).—*Water-Plants.*—Bearing in mind the fact that the essentials for the growth of every plant are, (1) Adequate food and water; (2) Adequate temperature; (3) Adequate supply of oxygen for respiration, we may come to a conclusion as to the mode in which water-plants fulfil these conditions. The fact of growth taking place in the water is an indication that there must be food in solution in the water, and likewise a supply of oxygen. Absorption of food takes place over the whole surface, and thus, as the roots are not required for food-absorption and

for fixation, these organs are either altogether wanting, or, if present, are very feebly developed. Ascertain in each particular case how far the water-plant under examination differs from the normal land-plant.

1. Examine the *water-crowfoot*. (This plant is distinguished by the possession, in early summer, of fairly small white flowers, which are seen floating on the surface of the water. The flowers are of the butter-cup type.) Compare the leaves that are above the water with the submerged ones. How do you explain this difference in shape? Make drawings of typical representatives of each kind.
2. Examine the *water-milfoil*, which is completely submerged. Are the leaves similar in shape to the submerged ones of water-crowfoot? How is the plant benefited by the shape of its leaves?
3. Next examine the *common pondweed* (*Potamogeton*). Notice carefully the floating leaves. The upper surface is not covered with water. Water is treated here as when it falls on a duck's back. As the chief function of leaves is the assimilation of carbon dioxide from the air, the retention of this water on the upper surface of the leaf, on which the stomata are located, would prevent the carbon dioxide of the air from entering the stomata, and thus prevent carbon-assimilation taking place. All floating plants will be found to have some means of getting rid of the water that falls on their surfaces.

General Remarks (XXXIVb).—It is essential that

the stems of water-plants should be comparatively light. A heavy stem is not necessary, because the plant is held up by the water, and in addition, a light plastic stem adapts itself more readily to the vicissitudes of aquatic life, which are always associated with the constantly-changing level of the water. This lightness is secured by the formation of large air-spaces inside the stem. Not only so, but the plant also secures an abundant supply of oxygen for purposes of respiration. In the case of floating plants these air-spaces form a continuous system, which is connected through the stomata with the atmospheric air. In the case of plants that are completely submerged the spaces are filled with air obtained by withdrawal from solution of the air contained in the surrounding water.

4. As other examples, the arrowhead, the water-lilies (yellow or white), waterweed (*Elodea*) and duckweed may be taken. In all cases note the following:—

(1) Whether leaves are floating or submerged, or both.

(2) Whether the water changes its level to any considerable extent, and if so what arrangements are possessed by water-plants to adapt themselves to this change of level.

(3) Whether all the leaves are similar in shape; particularly compare those that are above with those that are below the water.

(4) Whether the upper surface of the floating leaves is wet or dry.

(5) The appearance presented by a cut section of the stem. Sketch.

(6) The location of the vascular bundles in-

side the stem. Are they arranged centrally or nearer the outside? Remembering that the vascular bundles form the chief stiffening material of a stem, which arrangement would give to the plant greater swaying power, bundles arranged at the centre or forming a ring near the outside?

Aquarium.—Fit up an aquarium as follows. Place the roots of the plants firmly in a layer of soil at the bottom of a tank. Cover this with a layer of well-washed river sand and fill up with water very gently, taking care not to disturb the prepared layers. The sand will need skimming from time to time. Stock with good healthy water-plants, and it will also be found advantageous to introduce such small aquatic creatures as minnows, water-snails, etc.

XXXV.—SEASHORE PLANTS

General Remarks (XXXV).—Many plants are so situated that they possess a very precarious water-supply. Such plants have, in the course of evolution, either reduced their leaf surface or developed a water-storing structure. Plants growing in the sand are of this nature, for water runs through the sand very quickly, and in consequence the plants growing in it have often to face a drought which would very soon kill any ordinary plant. Again, the presence of saline salts in solution in such soils prevents the free absorption of water, which is another reason for economizing the water-supply. Sand-plants are of 2 kinds.

1. Those which merely *prefer* a sandy soil, though found elsewhere.

2. *Strand-plants, i.e.,* sea-coast plants which have become

acclimatized to the presence of salt and are found only at the coast.

1. Examine the sand-spurrey, or wormwood, or golden rod, or any other plant which you have observed to grow better in sandy than in any other soil. Examine with reference to the following points:—
   (1) Are the leaf surfaces reduced?
   (2) Are the flowers large or small?
   (3) Are the leaves thick and fleshy or prickly or hairy?
   (4) Has the plant a stunted habit?
   (5) Do the leaves show sunken stomata?
2. Then collect one or two plants that you have seen growing only on a sandy shore or in a salt-marsh, such as scurvy-grass, sea-plantain, sea-thrift, etc. Remembering that the plant seeks to reduce its need for absorbing water to a minimum, in order to take in as little salt as possible, ascertain in each case how this is effected. Seek for—
   (1) Reduced leaves.
   (2) Spiny leaves.
   (3) Leaves with a thick, leathery surface.
   (4) Small flowers.
3. Make a list of all the plants of this kind that are growing in your neighbourhood, noting in each particular case the nature of the soil in which it grows, whether a rocky shore, or a sand-bank, or a muddy salt-marsh.

The commonest strand-plants are the following:—sea-holly, orache, sea-blite, saltwort, sea-purslane, seakale, sea-

spurge, sea-milkwort, sand-sedge, rest-harrow, thyme, birdsfoot-trefoil.

4. Make a collection in the same way of the plants that are found in a salt-marsh, and in the same manner ascertain the manner in which they have adapted themselves to their habitat. Sketch these plants, especially their leaves and stems, and note any points that are peculiar to them.

XXXVI.—HEDGE-PLANTS, PLANTS IN WOODS

GENERAL REMARKS (XXXVIA). — *Hedge-Plants.* — In studying these plants we must bear in mind the following points:—

1. The top of a hedge-bank is dryer than the lower part, and as plants which grow in a dry soil, require plenty of light, we shall expect to find on the top of a hedge-bank a large proportion of long-stalked plants, or else plants that have learnt to climb over other plants to get at the light.

2. The lower part of a hedge-bank is more moist and has more shade than the top part.

3. The lowest part of the bank will possess plants that have a tendency towards amphibious habits, and the same will apply also to the ditch itself, if there be one.

1. At the top of the hedge-bank examine such plants as the nettle, hedge-mustard, goose-grass, etc. Find out the means that they have adopted to secure an abundance of light. Have they long stalks, or are they climbing plants?

2. Make an examination of the plants growing in the lower part, *e.g.*, moschatel, violet, deadnettle, stitchwort, etc. Is the hedgerow, as a whole, fairly dry or somewhat damp?

3. Next examine the ditch itself and the very lowest part of the hedge and see if the plants growing there, have the peculiarities which you associate with water-plants (*see* XXXIV).
4. Find out which is the south side of the hedge and compare its vegetation with that of the other side, which necessarily receives less light, is more moist, and somewhat colder.

General Remarks (XXXVIb).—*Plants in Woods.*—The undergrowth in such places will largely depend on the shade afforded by the trees growing overhead and on the nature of the soil. Find out, in the case of any wood under examination—

1. The kind of trees growing overhead and the nature of the shade afforded by them.
2. The presence or absence of shrubs and under-shrubs.
3. The kind of soil underneath.
4. Whether the flowers have appeared before or after the leaves of the trees overhead.

The commonest of these plants are dog's mercury, wood sorrel, wild hyacinth (bluebell), primroses and wood anemone.

XXXVII.—WEEDS OF CULTIVATED AND ALLIED SOILS

General Remarks (XXXVII).—In studying these plants it is very instructive to make observations on a piece of *cleared ground*. Observe the kind of weeds that are the first to make their appearance. Ascertain whether the bulk of the first lot of weeds are annuals or perennials, whether they are plants with a very wide distribution, whether the

seeds of these plants have special methods of seed-distribution. Again, the position of the flower in the vegetable kingdom should be determined. The commonest weeds usually belong to the highest natural orders. If possible the same piece of ground should be studied for several seasons.

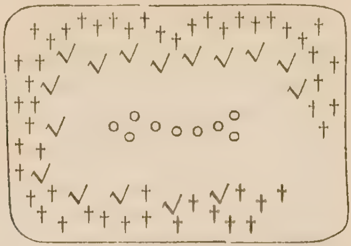
Look out for plants like the scentless mayweed, groundsel, shepherd's purse, hogweed, charlock, etc. These observations should be supplemented by observation of the plants that appear upon the following:—

1. Railway embankments.
2. Ballast heaps.
3. Rubbish heaps.
4. Lawns.
5. Gardens that have been allowed to go to waste.
6. Any piece of ground that has once been cultivated and subsequently abandoned.

In each case make observations with regard to the following points:—

1. The amount of moisture in the soil.
2. Whether the soil is flat or sloping, and, if the latter, the aspect of the slope.
3. The past agricultural history, so that some idea may be obtained of the richness of the soil.
4. Whether shaded or not by the neighbouring vegetation, *e.g.*, a clump of tall trees.
5. The nature of the soil (*see* XXXIII).
6. If the piece of ground be fairly extensive, see if different kinds of plants predominate in different parts of it. This is also particularly necessary when the ground is in the proximity of water. A rough plan of the ground should always be made and a symbolic sign adopted for each of

the plants that are found there in abundance. The following may serve as an example.



† = reeds.
o = bogbean.
√ = marsh marigold.

Plan of Ground under observation.

This scheme can be easily amplified. After a little practice an ordnance survey map of the neighbourhood should be procured and certain selected parts of it drawn on a fairly large scale. On these maps the plants most numerously represented could be symbolically represented as above described.

XXXVIII.—PLANT ASSOCIATIONS

General Remarks (XXXVIII).—After the student has mastered the names and general structure of the commonest plants it is a very useful exercise to ascertain which combinations of plants frequently occur together.

1. Select a small copse and arrange the plants that you find in it in the following manner:—

   Trees.—Find out which is the dominant species and, roughly speaking, what percentage of the whole is made up of this species.

   Ascertain which trees make up the remainder of the copse and whether the species are numerous enough to constitute sub-dominant trees.

Shrubs and Herbs.—Follow the same procedure with regard to the undergrowth.

By selecting, say a copse, in which the beech is the dominant tree, and one in which the birch is dominant, marked differences will be observed in the underwood.

2. Next select a plant, *e.g.*, wild hyacinth (bluebell), which you know grows only in one kind of place, and, selecting different spots, note down all the plants that are growing in association with the flower selected in the same wood, in the same field, etc., according to the spot selected. In course of time it will be found that many interesting facts will, in this way, be brought to light.
3. When it has been ascertained that a certain group of plants is very frequently found in association, the reason for this association should be inquired into.

(1) Have they characteristics in common which distinguish them from other plants, *e.g.*, adaptations for living in water, in sand, on a heath, etc.?

(2) Examine carefully the underground parts of these plants. Very often it will be found that they do not enter into serious competition with one another. See if the underground parts of one are superficially placed, whilst those of another explore the deeper parts of the soil, whilst possibly a third may have reserve material stored in a bulb, corm, tuber, etc.

XXXIX.—PLANTS IN THE SERVICE OF MAN

General Remarks (XXXIX).—Directly or indirectly every particle of food that we consume is obtained from the

plants, for the flesh of the animals that we eat, is built up by feeding on plants. Even in the case of the carnivorous animals the same statement may be made, for they also feed on the flesh of animals which has been built up by feeding on plants. So far as the food of mankind is concerned, in practically all cases we make use of the surplus of food which the plant had no *immediate* use for.

1. Revise the articles dealing with bulbs, corms, tubers, etc., and note how, in each case, a plant's storehouse is the portion that is removed for human consumption.
2. To show that the storehouse of a plant's food is not confined to any one particular part of the plant, examine the following:—

   a. A piece of *sugar-cane.* Here the stem, without any alteration in shape, is the storehouse.

   b. Any nut. E.g., Barcelona nut, walnut, hazel nut, etc. In these cases the food is stored in the seed.

   c. Any *tuber* or *corm* or *bulb* or *rhizome.* In all these cases the storage is underground.

   d. A *grape* or *orange* or any similar fruit. The food is stored in the fruit.

   e. A *cabbage*, of which the leaves are eaten.

   f. A *cauliflower*, of which the young inflorescence is eaten.

   g. A *carrot*, in which food is stored in the root.

The wood of plants is useful to mankind in a vast variety of ways.

3. Ascertain the kinds of timber that are made use of for the following purposes:—

   1. For making furniture.

2. For making fishing-rods.
3. For making the body of ships.
4. For making penholders.
5. For making cricket-bats.

This problem can be amplified to suit requirements. It should be easy to obtain samples of different kinds of wood.

4. Ascertain as far as is possible which characteristics have led to the choice of a particular kind of wood for a particular purpose.

The following notes will be found useful:—

Scotch Pine is very resinous and cannot be worked into a fine surface. The wood, however, is soft, and owing to the contained resin resists decay very well.

White Deal or *Spruce* is easy "to work" and gives a beautiful lustrous surface.

The *Oak* is strong, tough and elastic. It does not shrink much in seasoning. Its weight also is not excessive.

Walnut is hard, heavy, and makes excellent veneer for the cabinet-maker.

Ash.—Of moderate weight and hardness, but even and close in the grain so that it is tough, elastic, and very pliable.

Birch.—Chief virtue is that it is easily worked. It is not strong or durable.

Elm.—Most durable of British timbers.

5. A selection should now be made of those substances which are not strictly food but are made use of as condiments, as stimulants, for medicinal purposes, etc.

a. Study the peppers and as many of the

other spices as you can get hold of. Find out to which part of the plant each belongs.

b. A few coffee grains should be procured and studied, and if possible also the whole fruit, each of which contains two cavities with one grain (=seed) in each. Procure also a few Chicory *roots*.

Compare Chicory with coffee.

a. Chicory, when rubbed between the fingers, balls up, on account of its greater capacity, as compared with coffee, for taking up moisture.

b. Fill two tumblers with water and place into one a teaspoonful of coffee, and into the other a teaspoonful of chicory. See if their different solubilities in water is a guide in enabling you to distinguish coffee from chicory.

c. If possible procure a tobacco-plant and a tea-plant and jot down a few notes on the structure and general habit of the plants. The active principles which make these plants valuable are found in the leaves.

d. Cocoa is obtained from the seeds of the cocoa plant. The cocoa pod is large (6-8 ins. long) and packed with these seeds. After examining a little of the cocoa of a good brand under the microscope, buy a little of the cheapest stuff you can procure and note under the microscope how much is cocoa and how much starch.

This line of study can be extended in many directions, according to the facilities which the student possesses.

APPENDIX

NOTE 1. *Fertilization.*—Fertilization consists essentially in the union of a male element with a female element. In the case of flowers the male element is represented by the *pollen-grain*, and the female element by the *embryo-sac* which is embedded in the ovule. When the pollen-grain alights on the stigma it exudes a digestive fluid (ferment) which breaks up the tissue of the stigma that is in its immediate neighbourhood. It then sends out a tube (pollen-tube), which is thus easily able to bore its way through the broken-up tissue of the stigma. By dint of further exudation of the digestive fluid, the tube is enabled to bore its way right down through the tissue of the style, and finally to enter the cavity containing the ovules. It then works its way direct to the micropyle of the ovule and penetrates into the embryo-sac. There the male and female elements unite and fertilization is said to have taken place. The whole of the contents of the pollen-tube does not fuse with the whole of the contents of the embryo-sac; the essential part of the fertilization consists in the union of one of the two nuclei of the pollen-tube with one of the seven nuclei of the embryo-sac. The future plant is derived *entirely*, by growth and division, from the two fused nuclei.

NOTE 2. *Test for Sugars.*—The test for sugar is based on the fact that some sugars are able to remove oxygen from certain substances, thus reducing the latter to a less oxidized condition. Thus cupric oxide can be reduced to cuprous oxide, thus:

$$4\,CuO = 2\,Cu_2O + O_2.$$

Now cuprous oxide is an insoluble, yellowish-red substance, and its presence, therefore, is easily detected. Try the following experiment with grape-juice:—Add to a portion of this liquid a large amount of

potash and a drop or two of a solution of copper sulphate. A precipitate of copper hydroxide will be formed which will immediately dissolve in the excess of potash. Boil and note the formation of a precipitate of the insoluble cuprous oxide. This shows the presence of a reducing sugar. In the case of a non-reducing sugar like cane-sugar, this must first be converted into a reducing sugar. To a portion of a cane-sugar solution add a drop of hydrochloric acid; boil for some time, when the cane-sugar will be converted into a reducing sugar. The above test can then be applied.

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